*Chapter Ten*

# MISCELLANEOUS DESIGN

This chapter contains guidelines and criteria for the design of roadway elements that do not logically fit within the general categories of information covered in other chapters.

## 10.1 CONTEXT SENSITIVE DESIGN

Context sensitive design is a term used to identify a design process that balances the design features of a project with:

- User safety,
- Transportation system needs,
- Accessibility and mobility,
- Preservation of historic sites and districts,
- Natural and man-made environmental concerns,
- State and local economic needs, and
- Preservation of community values

Context sensitive design recognizes that the application of uniform engineering standards to specific transportation projects is not always possible. Transportation facilities are not constructed through consistent, uniform settings. In reality, landscapes are constantly changing and preventing the easy application of engineering standards. AASHTO and this manual respond to this problem by developing different sets and ranges of standards to apply to the most common types of landscapes encountered. There are standards for rural and urban environments, different types of terrain, and varying functional classes of highways. However, the designer still finds it difficult to always meet these variable standards. Historic sites, sensitive environmental areas, such as wetlands and natural areas and community concerns along with the mixing modes of transportation such as pedestrians, bicycles, and public transit, within the same right-of-way often conflict with the routine application of established engineering standards.

The context sensitive design approach is used to develop projects that achieve protection of community, historic, and environmental values while utilizing scientifically developed engineering standards that will result in a legally defensible, safe facility for the user. This process allows the designer to address community concerns while meeting the intended transportation needs, minimizing adverse impacts and enhancing the project area. Context sensitive design requires careful listening and understanding of the values placed on the project area by citizens, agencies, special interest groups, and local governments. It requires thoughtful and often creative design solutions.

### 10.1.1 TYPES OF PROJECTS

There are many types of projects in the Department's annual Transportation

Improvement Program. Projects are developed to preserve the integrity of the current system, to restore or increase the capacity of the system, to improve the safety of the system, to maintain suburban streets, and address other concerns in communities and municipalities.

For the highway system, the types of improvements used to expand capacity are new construction on new alignment and reconstruction of an existing roadway in-place, involving adding lanes and other capacity improvements. They also cost the most and have the greatest social, economic and environmental affects on adjacent areas. Projects on new alignment often do not have the land use restrictions or the historical, operational and safety problems associated with improving an existing roadway. This means that higher design standards can be attained. In contrast, reconstructing an existing roadway in-place to address capacity, safety and operational problems is difficult without introducing flexibility into the design. Since significant geometrical changes are not normally viable, historical data, such as traffic growth, traffic patterns, and types and frequency of accidents, become an important part of the decision-making process in assessing and correcting existing problems. Because of the difficulties in making changes, particularly in vertical and horizontal geometry, this analysis will determine if not meeting the highest design criteria is an acceptable alternative.

There are other types of projects ranging from restoring and/or maintaining a facility's capacity to resurfacing existing roadways to maintain their rideability. Many of these projects lend themselves to flexibility in choice of design options.

Ensuring that a project will be designed within the context of the community meeting the expectations of both the motorist and the community at large is the result of an early, continuous and meaningful public involvement process. Through a continuous public involvement process, the designer is assured that the purpose and need of the project is fulfilled, the needs of the community are understood and addressed, and new or additional issues do not arise during the final design or construction phase.

### 10.1.2 DESIGN STANDARDS

Each project should begin with determining the applicable design standards as published by AASHTO and this manual. In the context sensitive design environment, it is recognized that there are limitations, constraints, community values and other factors that require the designer to look beyond the full standards for a workable solution. Meeting the full standards for an entire project may not be possible but design alternatives that combine multiple substandard dimensions simultaneously are not acceptable. Arbitrarily lowering a project design speed to solve a problem in a sensitive area is also not an acceptable alternative. All major geometric values are based on design speed and lowering this value would preclude the use of appropriate standards where they are attainable. Where a non-standard element, dimension or approach is used, the potential adverse operational affects should be mitigated by wider paved areas, appropriate advanced signing, increased vertical or horizontal sight distance or other treatment.

The selected design criteria should properly reflect driver safety, desires, expectations, comfort and convenience. Of course there are many contraints, including terrain, land use, roadside and community effects, and cost considerations. A project is designed based on accepted design criteria, practices, guidelines, and standards. Appropriate dimensions and values are selected to produce a facility of a given quality, provide a reasonable degree of safety, and consistent expectation (standard design) for the user. Transportation Research Board’s Special Report 214

*Designing Safer Roads* is a valuable resource document when evaluating the various design parameters in reaching a safe and flexible set of design standards meeting project intent.

### 10.1.3 OPERATIONAL CONSISTENCY

Although, designs may not meet all of the applicable design standards, they can provide design/operational consistency. Ensuring the continuity of designs means that a motorist can travel to any state, city or town and, depending upon the situation encountered, react in the same driving manner e.g. all ramps are signed uniformly and have deceleration lanes. In responding to the many issues that each project faces, there is a need for flexibility in the design process, while maintaining uniform design practices. Flexibility is achieved by recognizing outstanding issues and making changes while recognizing the tradeoffs incurred. Flexibility in design should not unduly compromise the user's safety. Each project is unique and has its own community values, social, economic, and environmental constraints. Context sensitive designs recognize and address those unique elements that preserve or enhance community values.

AASHTO design standards do have a measure of flexibility, usually stating a maximum and minimum value. Many of these values were established many years ago with assumed conservative variables, some derived theoretically and others empirically. Design features that fall outside normal design criteria and accepted practice should be documented, if necessary, with a formal "Design Exception". The key to minimizing liability is documentation of major design decisions in terms of safety, capacity, route compatibility, time to construct, environmental, historic, and aesthetic considerations, and construction costs throughout the project development process. Many design options have operational experience from past projects, including accident history.

### 10.1.4 DESIGN CRITERIA

Design criteria have historically provided consistency in the quality, appearance and operational performance of the highway system. They are based on data available for successful operational performance, as well as theoretical modeling and field-tested research. AASHTO's *A Policy on Geometric Design of Highways and Streets* (the Green Book) and periodically issued supplemental reports and guidelines catalogue this data for use by designers. The Green Book contains nationally accepted design criteria for new construction or reconstruction projects that are generally applicable for all 50 states.

This manual utilizes criteria contained in the Green Book to define design standards to address transportation needs and community values as envisioned in this State. Design data in the Green Book is intentionally developed to be conservative because highway alignments are of a permanent nature, and projects are initially expensive to construct and very difficult and expensive to correct if there are safety problems. The public expects the design professional to design it right the first time, meeting the users' operational needs and safety expectations.

Since the criteria is conservative in many areas with a significant margin of safety, there is room for creative yet safe designs when a designer has to look beyond the criteria to meet a constraint or issue that arises. Again, documentation of accepted changes in design criteria is essential.

### 10.1.5 DESIGN CONTROLS

Design controls include: functional classification, design speed, traffic volumes, traffic mix, terrain and location. The design team, working with the public, can identify constraints that will require flexibility in the design criteria.

#### 10.1.5.1 FUNCTIONAL CLASSIFICATION

A facility's functional classification and design speed are two major factors in setting the design criteria. The functional classification groups streets and highways based on the type of trips, mix of traffic, accessibility to the facility and the role of the facility in the total transportation system. The functional classification system establishes a heirachy based on the level of service to be provided for the users. This service ranges from the high level of service provided by the interstate system to local streets. Local streets provide a low level of service for through traffic movements but support safe local access and address community mobility needs.

The AASHTO Green Book relates the functional classification to design criteria, particularly design speed and geometrics. As a result of variances of design criteria within the functional classification system, there are overlapping ranges of values. This allows flexibility for choosing a design that is most appropriate within the determined functional classification. Land use is very dynamic, thus changing the character and use of a facility leading to a functional classification change. At the same time there may be strong support for the preservation of the existing character of a facility. The development group will become aware of this during the public involvement phase of both the planning and/or design processes.

#### 10.1.5.2 SPEED SELECTION

In design, there are three speed concepts used: running speed, operating speed and design speed. The difference between these three values can be significant. Running speed is the actual speed of a vehicle over a specified section of highway. For evaluating road-user costs and benefits, the average running speed is used. This value varies during the day based on the traffic volume which, depending upon the roadway characteristics may have to be field measured at several locations to truly reflect the average running speed. Operating speed is the speed at which drivers are observed operating their vehicle during free flow conditions. The $85^{th}$ percentile of the distribution of observed speeds is used to statistically describe the operating speed associated with a particular location or geometric feature. Design speed is a selected speed used to determine the various geometric design features of the roadway.

Design speed usually controls the design features. Selecting a design speed is not a simple task. Using a design speed as high as practical may ensure that drivers can drive as fast as comfort level will permit but may not be the best method in determining the design speed. In practice, design speed is selected to accommodate a high percentile of drivers.

The determination of a design speed is affected by many factors including: the capabilities of the drivers and their vehicles, physical characteristics of the roadway and its roadsides, the weather, the presence of other vehicles, and speed limitations. Selecting a higher design speed imposes more design constraints. Selecting a design speed based on an artificially low operating speed that does not meet the expectations of a high percentage of drivers can significantly degrade the safety of the facility.

Design speed should be logical with respect to the topography, anticipated operating speed, the adjacent land use, and the functional classification of highway. The design speed chosen should be consistent with the speed a driver is likely to expect on the facility being driven. A lower design speed should not be selected where physical conditions are such that drivers are likely to travel at high speeds. Drivers adjust their speed not to the importance of the facility, but to their perception of the physical limitations and traffic flow. See Section 2.3.3 and Section 3.2.1 for more discussion on the selection of an appropriate design speed.

Proposing an alternative design speed for a project or a segment of the project is not recommended for inclusion in the design exception process. Instead, individual geometric features should be evaluated within the selected design speed and addressed as exceptions if necessary. As discussed previously, most design features have an acceptable range of values that will meet driver expectation and provide acceptable driver safety.

Using the posted speed as the design speed is also not recommended. The design speed should be a minimum of 5-mph [10 km/h] over above the posted speed. Design speed usually approximates the $85^{th}$-percentile speed value as determined by observing a sizable sample of vehicles, but is not the highest speed that might be used by drivers unless reasonably enforced.

**10.1.5.3 TRAFFIC CONSIDERATIONS**

The importance placed on the operational and safety characteristics of a project is in direct proportion to the traffic volume and composition. Experience shows that the greatest contributor to the risk of an accident is traffic volume. Thus the volume of traffic may be a primary factor in decisions on design exceptions.

The designer uses two traffic volumes, current and projected in setting design controls. Depending upon the type of facility, perceived need, and existing traffic, a five or ten-year projection may be the control. New construction and reconstruction projects where increased capacity is the goal are designed to meet the needs of a projected 20-year traffic volume. Traffic forecasts are based on technical analysis, policy consensus (the State's vision of the future transportation network), anticipated type and intensity of land use, future economic activity, and other factors. Large variances with one or many of the factors used in the modeling process to project future traffic can and have occurred in the past. Some projects have exceeded their traffic projections in a very short time span and become functionally obsolete, some have never reached their projected traffic volumes and others have taken longer then the projected year to reach assigned design volumes. Context sensitive design recognizes the inherent limitations and uncertainties associated with long term traffic forecasting.

For setting design features, the forecasted daily traffic volume is further refined to develop an appropriate design hourly volume, DHV. The DHV initially selected is the $30^{th}$ highest hourly volume of the year. Exceptions may be made on roads with high seasonal traffic fluctuations or other conditions, where a different volume may need to be used. Available projection techniques lead to estimated volumes. Selection of a design hour volume should reflect other constraints and controls reflecting the project's purpose and need. High DHV’s usually result in wider lanes, more lanes, and greater costs. All of these tend to increase disruption to the community and conflict with other important issues.

Another design control reached through analysis of current and forecasted traffic is the predominant type of driver and vehicle expected to use the facility. With the perception that safety will be greatly enhanced, design controls are conservatively established regarding the capabilities of the driver to react physically and mentally to conditions that may be encountered. The result of this analysis is the selection of a design vehicle. Projects involve a variety of adjacent land uses, types of intersections and alternative modes of transportation and may have several design vehicles. Each design vehicle has physical and operational characteristics that affect the design controls. These include acceleration and deceleration capabilities, ability to climb steep grades, sweep-path dimensions of turning vehicles, and height of the driver's eye. There is a range of design vehicles and associated characteristics. There is no mandated design vehicle. The choice(s) should be made with the knowledge of the tradeoffs involved and input from the community and public while being cost and space effective.

### 10.1.5.4 LEVEL OF SERVICE

How the user perceives a design to meet the traffic operational conditions for the selected design hourly volume is defined as the level of service. Level of service can be quantified in terms of running speed, travel time, freedom of movement, traffic interruptions, comfort and convenience. Different types of highways have different attainable or expected levels of service. The various elements that make up each type of highway depend upon the selected level of service. Rural highways are expected to operate at higher levels of service and facilities in urban areas at lower levels with acceptable congestion. The level of service selection in context sensitive design recognizes the need to tailor the level of service to other design controls and constraints, within the context of the project's purpose and need.

## 10.1.6 HIGHWAY GEOMETRIC ELEMENTS—DESIGN AND SAFETY CONSIDERATIONS

Geometric design controls the horizontal, vertical, and cross sectional elements throughout the project including intersections. Selection of geometric criteria should recognize the characteristics of the potential users and the physical and operational characteristics of their vehicles. Using absolute design criteria values can lead to conflicts with community values and local constraints. In developing a context sensitive design, it may be necessary to design using the flexibility that lies within the standards while maintaining acceptable and predictable safety and operational characteristics.

### 10.1.6.1 HORIZONTAL ALIGNMENT

Horizontal alignment is comprised of tangents and circular curves used to adjust the alignment laterally to meet land use and terrain constraints. Horizontal curvature is a controlling feature of a design. Curve selection is based on the project's design speed and resulting superelevation rate. The transition sections between tangents and circular curves are also important elements in establishing horizontal alignment. AASHTO criteria in the Green Book are based on the amount of friction needed for the vehicle to track properly and the comfort perceived by the driver at the design speed under poor pavement conditions. Current design tables for friction are based more on driver tolerance than what is actually necessary to prevent loss of control.

Knowing that the assumptions in establishing the relationship of design speed to curvature are driver comfort and poor pavement condition will allow the designer to determine the risks in accepting a non-standard design. Reliable data on actual speeds, accident types and probable causes, and roadside conditions along the curve area will help the designer in this decision-making process. Studies show that safety is related to curvature and length of curves on higher speed facilities. On lower speed streets, there is little indication that there are safety affects associated with marginal curvature. However, where there is a predominance of higher profile vehicles with higher centers of gravity there is an increased need to meet or exceed the criteria.

In considering the safety risk of a design exception for horizontal curvature, AASHTO suggests evaluating the following factors:

- Risk is proportional to traffic volumes increase;
- Risk may generally be acceptable if the effective or nominal speed of the

proposed curve is within 5 to 10 mph [10 to 15 km/h] of the appropriate design speed of the curve;

- For roads with significant truck traffic, the risk increases due to a truck's tendency to overturn at lower speeds than passenger cars and the acceptable difference between design speed and operating speed is less;

- Risk varies proportionally with the length of curve;

- Risk of accidents within a curve is a function of the curve geometry, cross section, sight distance, and/or presence of intersections and driveways within the curve.

In providing a context sensitive design, the use of a range of curvature may be needed to mitigate various issues that arise on a project. Although it is desirable to use one minimum value for a design radius, it may not be practical. Substandard alignment decisions will require written documentation. Inclusion of other design elements to mitigate any adverse safety impacts should be considered. These elements could include additional signing, increased delineation, improved superelevation, lane widening, improving or widening the shoulder through the curve, improving roadside safety, increased clear zone, relocating or closing intersections or driveways within the curve, or providing higher surface friction pavements.

### 10.1.6.2 VERTICAL ALIGNMENT

The vertical alignment design elements are grade and sight distance. Grades are related to terrain and functional classification. Stopping sight distance governs vertical curvature.

Long or continuous steep grades can contribute to operational problems and safety risks. Flat grades can cause drainage problems leading to increased maintenance costs and wet-weather safety problems. Combining steep grades with sharp horizontal curvature creates a high-risk safety condition.

### 10.1.6.3 SIGHT DISTANCE

Sight distance is a function of the roadway alignment and cross section provided. Sight distance is the distance ahead for which a line of sight is provided for the driver under certain design conditions and assumptions. There are four types of sight distance—stopping sight distance, intersection sight distance, passing sight distance and decision sight distance. Stopping sight distance and intersection sight distance usually control the design.

Passing sight distance needs to be considered on two lane facilities as it affects operational quality and capacity but does not necessarily directly impact safety. Decision sight distance may be desirable in situations where there is a need to provide the driver with more time to make movement decisions.

Stopping sight distance criteria are based on operational models that reflect a driver's ability to see an object at given height above the roadway and react appropriately to avoid a collision. Sight distance can be limited by the vertical alignment of the road but also can be affected by a combination of horizontal alignment and sight obstructions beyond the edge of pavement. The model assumptions include size and placement of the object, the height of the driver's eye, driver perception time and braking reaction. The model applies to all levels of traffic volumes and all highway types equally. Since there are several assumptions that are affected by the evolution of the vehicle fleet, the age of the driving population and research on driver behavior, the range of acceptable stopping sight distance values is intended to be conservative. The model is not based on directly measurable safety values, the probability of a driver encountering the assumed conditions, or the severity of such an encounter. In other words, the design values for stopping sight distance and vertical curvature are unrelated to direct measures of safety, and generally provide substantial margin of safety against the actual risk of a crash. Sag vertical curve values are based on night operations where the controlling feature is the headlight beam on the pavement ahead.

The designer can assess the risk of a location with limited stopping sight distance using the following guidance:

- The risk of a sight distance restriction is related to the traffic volume exposed to it.

- The risk of a sight restriction is greater where other features such as intersections, narrow bridges, high volume driveways, or sharp curvature occur within the sight restriction.

- Where no high-risk features exist within the sight restriction, nominal deficiencies may not create undue risk of increased accidents.

- Horizontal restrictions such as buildings, signs, tree lines, etc. affect all types of vehicles equally.

- When possible, designers should use shorter sag vertical curves in favor of providing the longest crest vertical curves possible.

Lower ranges for stopping sight distance may be applicable for reconstruction projects where speeds and volumes are observable, accident records are available and the constraints of providing the desirable value may be cost prohibitive and adversely impact adjacent land uses.

#### 10.1.6.4 CROSS SECTION ELEMENTS

Cross section elements of a facility are the most visible and have the greatest physical affect on constructing or reconstructing a roadway. These include the lane and shoulder widths, median treatment, border areas, side slopes and ditch sections. In selecting these elements one must consider traffic volume, traffic mix, transportation modes, functional classification, available right of way and adjacent land use. Cross sectional elements become increasingly important as the severity of the alignment increases. Traffic operation and safety are very closely related to lane widths, shoulder availability, shoulder width and shoulder surface type.

The use of wider lane widths should be considered on higher speed facilities or those with high truck volumes. Lane widths are also influenced by horizontal curvature, as vehicles tend to move off-track and require room to avoid on-coming vehicles. In urban areas, narrower lanes may be considered as speeds are lower and the driver expects to encounter normal congestion and slower travel speeds.

Shoulders are a very important element of the roadway cross section. The shoulder serves as a part of the clear zone, improves capacity, accommodates drainage, provides an area for disabled vehicles, enables collision avoidance maneuvers, provides structural support for the traveled way and accommodates bicyclists and pedestrians. Where a full shoulder can not be provided, the designer should attempt to provide as wide a shoulder as possible that meets functional requirements.

The area adjacent to the roadway plays a major role in a facility's safety particularly with respect to run-off the road accidents. In applying context sensitive design philosophies, treatment of this area is affected by the established clear zone, costs, available right-of-way and probable impact on safety. Depending upon the roadside design provided, encroachment may not be a problem. When designing a project, overall safety benefits may be achieved by providing spot roadside improvements that may not necessarily be applicable throughout the length of a project.

Ideally a facility's roadside area should be a wide, firm, flat, hazard-free area that will permit the errant driver to recover and safely return to the highway. Early in the design process the designer normally establishes an area outside the travelway (edge of running lane) termed "clear zone." The effort and cost required in providing this area varies significantly from location to location. Deciding how much clear area to provide is proportional to the design speed, the projected traffic volume, historical accident data and the cost.

The most serious and obvious hazards are fixed objects that when impacted produce a sudden or instantaneous deceleration. These would include man-made objects, such as utility poles, overhead sign structures, buildings, retaining walls, large drainage inlets and outlets, exposed headwalls, and utility and traffic control boxes. Some objects only present a serious hazard at high-speeds while others are potentially serious hazards at any speed. The latter may require a more durable and effective barrier system.

The most hazardous natural fixed objects are trees. In context sensitive design, rather than clear the entire right-of-way, a designer needs to identify those trees most likely to present a significant hazard to the driver. Tree removal is a sensitive environmental and community issue. This perception must be considered when identifying trees to be removed. Where possible an analysis of accident history and visual evidence may indicate if there is a tree safety problem. If there are numerous trees, removing selective trees may not improve safety. Isolated trees lying close to the roadway present the most probable safety risk and should be removed or protected. Community interest, speed, volumes, and past operational history would all affect this decision.

Natural and created topography does play an important role in roadside design. Created topographical features enter into the design of a safe roadside throughout the state. These include steep backslopes in cut areas, steep sideslopes in embankment areas and unsafe median and ditch sections. The goal is to minimize the need and use of unsafe road sections when designing these elements.

Most projects involve some type of improvement to an existing facility. Fixed objects encountered can include utility poles, sign and lighting supports, mailboxes, fences, gates, commercial signs, unsafe rock outcroppings, bridge abutments and piers. In creating a safe roadside environment, the designer has five options to address fixed objects: (1) removal, (2) relocation, (3) modification, (4) shielding and (5) delineation. Although it may not be practical or cost-effective to treat all obstructions, studying and mitigating (where possible), each obstruction should be viewed as an opportunity to improve roadside safety.

The concept of a wide hazard-free clear zone is usually not practical in urban conditions where many roadside features come into play, such as pedestrian areas, utilities, streetlights, signs, ornamental structures, benches, on-street parking, and limited right-of-way.

Roadside safety should not be compromised in context sensitive design. To reach this goal the designer should:

- Avoid setting an artificially high or low design speed;
- Apply a consistent roadside treatment;
- Not be arbitrary in selecting a clear zone;
- Encourage the removal or relocation of fixed obstacles;

- Use safe landscaping and grading treatments; and
- Provide safe sight distances at intersections and all planted areas.

On multi-lane highways the median treatment is an important part of cross section design. The primary purpose of a median is to separate traffic, thus reducing the occurrence of head-on collisions. However, there are other benefits associated with medians that improve overall safety, traffic flow (vehicular and pedestrian) and aesthetics. The median may be raised, depressed or flat, and includes paved or unpaved shoulders, swales, or ditches. Medians also offer the opportunity for providing landscaping. Median width selection is a function of the available right-of-way, the border area needs and providing area to allow safe maneuvers and room for traffic devices. Median width meeting one or more of these needs has a large range of values. Wide medians are not always attainable but even narrow medians can provide positive benefits.

#### 10.1.6.5 INTERSECTIONS

Most projects will involve the treatment of intersecting roadways. Intersection design is important to a facility's efficiency, safety, speed, capacity, and user cost. Safe intersection design includes the following:

- Provision for adequate sight distance;
- Accommodation of appropriate traffic control devices;
- Provision of safe and efficient handling of turning traffic (left turns have the most conflicts);
- Avoidance of non-standard or confusing geometry, signing or other out of the ordinary treatments prior to or within the intersection; and
- Optimization of the capacity of the intersection.

The design features of an intersection are controlled by selection of the design vehicle, the larger the design vehicle the larger the intersection. Since space is limited, it may be better to accommodate the design vehicle that is anticipated to use the intersection most frequently. The available turning path templates were developed using relatively conservative dimensions. Computer programs are available to help the designer test the tracking of a design vehicle. When constraints do not permit meeting the full geometry and lane widths of the design vehicle, consideration should be given to moving roadside objects, such as signal poles, highway lighting, signs, etc. farther from the edge of pavement. When not providing the full standards, it can be expected that there will be occasional encroachment outside the designated lane area. These areas should be evaluated for type of curb, particularly if there are fixed objects. In addition, aesthetic and traffic calming improvements should not be placed in anticipation of encroachment. If the intersection can not accommodate the desired turning lane arrangements, different traffic control methods may be used including turn prohibitions, special signal phasing, advanced signing or other measures.

### 10.1.7 MAINTAINABILITY

All designs must be continually evaluated for maintenance needs. The frequency, ease, cost, accessibility and safety of maintaining selected design elements are essential to measuring a successful project. Much of the design effort, particularly for context sensitive projects that use innovative and unique concepts or construction materials, can be negated if they can not be properly maintained.

## 10.2 TRAFFIC CALMING

In communities where speeding and/or cut-through traffic has been identified as a problem, it may be appropriate to consider the feasibility of one or more traffic calming measures. Such measures are intended to encourage adherence to posted speeds and/or discourage inappropriate routing of non-residential or non-local traffic through communities.

The DelDOT *Traffic Calming Design Manual* (TCDM) and the joint FHWA-ITE *Traffic Calming-1999* publication provide general guidance regarding the appropriate use, design, signing and marking the traffic calming measures approved for use in Delaware. It also describes the steps necessary to nominate, select, develop and implement traffic calming projects. In the event it is necessary to modify or remove an existing traffic calming measure, the TCDM provides guidance in that matter as well.

## 10.3 TRAFFIC BARRIERS

The purpose of traffic barriers is to reduce fatalities and injuries by preventing a vehicle from leaving the traveled way and striking a fixed object or terrain feature. However, it is recognized that a protective barrier is, in itself, a roadside obstacle and may not contribute to safety. Therefore, under most situations a barrier is warranted only when the consequences of leaving the roadway are likely to be more severe than a collision with the traffic barrier.

Other factors not to be overlooked by the designer in determining the need for barriers include an analysis of a project's accident history, types of accidents, adjacent land uses, pedestrian and bicyclist use, and adverse geometrics such as sharp curvature combined with poor sight distance.

Barrier performance is based on its ability to contain and/or redirect the errant vehicle. The behavior of a vehicle during impact is very complex. Barrier designs are developed through full-scale crash tests under controlled standardized conditions. Sections 5.1 and 5.2 of the *Roadside Design Guide* provide the details on the testing programs.

Because of the on-going testing programs, the available types of barriers and installation details for barriers are dynamic. The Department's Standard Construction Details, the Standard Specifications, and Special Provisions are continually modified to reflect changes recommended by AASHTO, FHWA, the Transportation Research Board and other agencies that oversee the barrier testing programs. The testing results are published and recommendations made to transportation agencies for selecting approved barrier types based upon the anticipated service needs.

The three most commonly used barriers discussed in this section are:

- Longitudinal barriers,
- Median barriers, and
- Impact attenuators.

### 10.3.1 DESIGN OPTIONS

A designer's goal is to develop an acceptable design that does not warrant barriers. The designer has several options after an initial determination has been made that a traffic barrier is warranted. Design options for the treatment of the various conditions encountered within a project's limits should be evaluated in the following order:

- Examine the proposed and existing roadside features to determine the feasibility of eliminating the need for a barrier;
- Remove the obstacle or redesign it so it can be safely traversed, that is, design traversable slopes, extend pipes beyond the clear zone, install safety end sections, etc.;
- Relocate the obstacle to a point where it is less likely to be struck;

- Reduce impact severity by using an appropriate breakaway device;

- Redirect a vehicle by shielding the obstacle with a longitudinal traffic barrier and/or crash cushion; and

- Delineate the obstacle if the above alternatives are not appropriate.

### 10.3.2 GUIDELINES

The criteria and procedures for barrier need and design are outlined in the AASHTO *Roadside Design Guide*. Using the charts and graphs found in the guide in determining the need for barrier is relatively simple. However, this method does not consider the probability of an accident or the costs of either shielding the condition or leaving it as-is. A method has been developed that establishes warrants based on a cost-benefit analysis that considers factors such as design speed and traffic volume. The guide includes a computer program for evaluating the costs and benefits of design options for safe treatment of roadside hazards. Performing this analysis may be a useful tool for determining the preferred safety treatment.

The following are important elements to consider in determining the need for and selection of types of barriers:

- Performance capability,
- Deflection,
- Site conditions,
- Compatibility with other design Features,
- Cost,
- Maintenance (routine and collision, storage of spare parts, and simplicity of repair),
- Aesthetics, and
- Past performance.

### 10.3.3 LONGITUDINAL BARRIERS

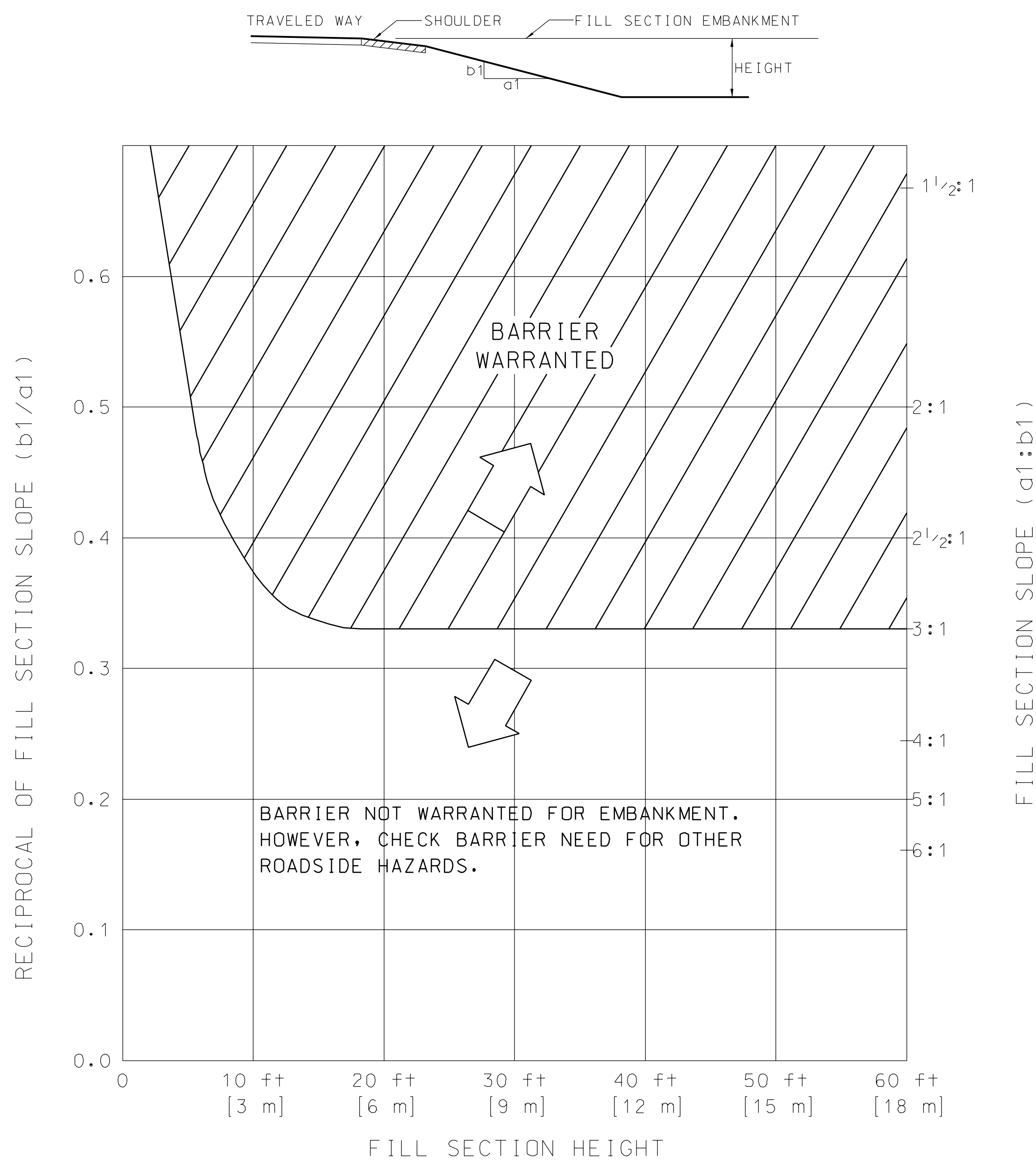
W-beam steel guardrail and concrete safety shape barriers are most commonly used for longitudinal shielding. Geometric criteria for steel beam guardrail, along with illustrative typical installations, are in the Department's Standard Construction Details. The need for barriers is directly related to the selected cross sectional elements as discussed in Chapter Four. This section is directed principally to guidelines and general considerations for designing guardrail installations.

Hazards that may warrant shielding by a roadside barrier can be placed in one of two basic categories, embankments or roadside obstacles. Protecting pedestrians and cyclists from vehicular traffic with a barrier may also be warranted.

ADT, embankment heights and slope rates are the primary factors in determining barrier needs for fill sections. Figure 10-1 shows guardrail warrants for various combinations of embankment height and slope. A barrier installation is warranted where the point of intersection falls above the curve.

Side slopes on an embankment should provide a reasonable opportunity for recovery of an out-of-control vehicle. Flat slopes characterize a traversable embankment and generous rounding of the slope breaks. In instances where construction of flat slopes is not feasible or practical, installing a barrier may be necessary. Where slopes are 3:1 or steeper, designers should first consider the alternative of the adjusting the embankment slopes, thus avoiding the use of barrier.

***Figure 10-1***
***Guardrail Warrants for Embankments***



Roadside obstacles are classified as "non-traversable hazards" and "fixed objects". If it is not possible to remove or relocate a hazard, then guardrail may be necessary. However, guardrail should be installed only if it is clear that a barrier offers the least hazard potential and is the most cost-effective in terms of safety benefits.

In the case of non-traversable hazards, a general criterion is that barrier protection should be provided for streams or bodies of water that may constitute a hazard and areas of rough rock cuts.

Warrants for barriers to shield roadside obstacles involve different considerations. A principal consideration is the required clear zone width. Clear zone selection is discussed in Chapter Four. Barriers are normally not required to shield a fixed object outside the specified clear zone. Roadside obstacles in the form of fixed objects include items such as trees, bridge piers and abutments, culvert headwalls, sign posts, light posts, and non-traversable drainage structures. In the case of drainage structures, the designer should consider extending pipes or using traversable end treatments to eliminate the hazard. Guardrail shielding normally is warranted if obstacles or fixed objects are within the limits of the lateral clear zone. Accepted designs of "breakaway types" of poles and posts are not considered fixed objects.

The need for guardrail at a bridge approach is based on the clear zone requirements for fixed hazards. For twin bridges, the length of approach rail on the median side of each bridge should be long enough to prevent an errant vehicle from impacting the bridge rail end of the other bridge. If it is within, or close to, the design clear zone, the guardrail should be long enough to protect the area between bridges at the edge of the clear zone. Consideration should be given to including a transverse berm between the endwalls of the two bridges.

Special treatment is required where side entrances interrupt the installation of guardrail. Additional flares and end treatments may be required, or it may be more economical to eliminate the need for guardrail.

An area of concern is what has been termed the "innocent bystander" problem. In most of these cases, the conventional criteria presented above cannot be used to establish barrier needs. For example, a major roadway or street may adjoin a schoolyard, but the boundaries are outside the clear zone. Since it is outside the clear zone, a barrier would not normally be required. However, if there is a reasonable probability of an errant vehicle encroaching on the schoolyard, a barrier could be considered and installed.

Protection of pedestrians and cyclists is another area of concern. As in the case of bystander warrants, there are no objective criteria for pedestrian and cyclist barrier warrants. On low-speed streets, a vertical curb may be sufficient to delineate pedestrians and cyclists from vehicular traffic. However, at speeds over 25 mph [40 km/h], a vehicle may mount the curb for relatively flat approach angles. Particularly where sidewalks or bicycle paths are adjacent to the traveled way of high-speed facilities, some additional provision may be required for the safety of pedestrians and cyclists.

### 10.3.4 BARRIER PLACEMENT

After the decision is made that a barrier is warranted, there are several factors that need to be considered for its placement. These are:

- Lateral offset from the edge-of-traveled way,
- Terrain effects,
- Flare rate, and
- Length of need.

**10.3.4.1 LATERAL OFFSET**

A roadside barrier is normally placed as far from the traveled way as possible, while still maintaining the operating characteristics of the selected type of barrier. The greater the distance the better chance for the driver to recover control of the vehicle. In addition, some barrier installations may obscure a driver's sight distance if placed too close to the traveled way.

Placing the barrier at a uniform offset distance will not only be more aesthetically pleasing but provides the driver with a feeling of security and comfort when approaching a series of protected obstruction areas. The distance from the edge-of-traveled-way, beyond which a roadside object will not be perceived as an obstacle and result in the driver reducing speed or directing the vehicle away from the barrier, is called the shy line. This theoretical distance is different based on design speed and is shown in Table 5.5 in the *Roadside Design Guide*. For long continuous runs of barrier and barrier placed beyond the shoulder, the shy line offset criterion usually does not control barrier placement.

Another consideration in the lateral placement of barrier is the expected deflection of the system selected. The distance from the barrier to a rigid obstruction should not be greater than the dynamic deflection of the system based upon data from actual impact tests under controlled conditions, i.e. vehicle weight, speed and impact angle.

In embankment areas that must be protected, it is important that the width of embankment be sufficient to adequately support the posts to ensure proper operational characteristics of the barrier, see the Standard Construction Details.

There may be considerable deflection in barriers when impacted by a vehicle. Figure 10-2 shows the dynamic deflection of W-beam and concrete safety shape. If a roadside obstacle is too close to the back face of the rail or post, there may be danger that the rail will deflect all the way to the obstacle. Under these conditions, designing the post spacing closer than normal will reduce the potential deflection of the guardrail. If the obstacle is more than 3 ft [0.9 m] behind the back of post, a post spacing of 6 ft 3 in [1905 mm] should be used.

For obstacles located from 2 to 3 feet [0.6 to 0.9 m] behind the back of post, a post spacing of 3-ft 1-1/2 in [952 mm] should be used. If the obstacle is less than 2 ft [0.6 m], a rigid concrete barrier could be used. These deflection guidelines are based on having a proper end anchorage and posts installed in stable soil.

**10.3.4.2 TERRIAN EFFECTS**

A roadway's cross section is important element in a vehicle's performance when approaching or impacting a barrier. Barrier systems perform best when vehicles have all wheels on the surface and its suspension is in a normal position at the point of impact. The two common features of concern are curb and the approach slope. These features may cause a vehicle to vault over a barrier or strike the barrier too high or too low.

Vehicles striking curbs can change trajectory depending upon the size of vehicle, suspension characteristics of the vehicle, its impact speed and angle, and the height and shape of the curb. Impact testing has shown that the use of any guardrail/curb combination where high-speed, high-angle impacts is not an acceptable practice. If there is not other alternative, than the curb should be limited to 4 in. [100 mm] and the guardrail stiffened.

Vehicles transversing slopes steeper than 10:1, depending upon their impact angle and speed, may go over or impact the selected barrier too low. The *Roadside Design Guide* in section 5.6.22 and Figure 5.22 details the effect of slope rate on vehicle and barrier performance. The conclusion of the discussion is that roadside barriers perform most effectively when they are installed on slopes of 10:1 or flatter. A slope of 6:1 may be a problem and Figure 5.23 in the *Roadside Design Guide* gives a recommended barrier location when using 6:1 slopes.

***Figure 10-2***
**Dynamic Barrier Deflection**

| Barrier Type | Post Spacing | Dynamic Deflection (From back of post) |
|---|---|---|
| **Blocked-out W-Beam Steel Post** | 6 feet 3 inches [1905 mm] | 3 feet [0.9 m] |
| **Blocked-out W-Beam Steel Post** | 3 feet 1-1/2 inches [952 mm] | 2 feet [0.6 m] |
| **Concrete Safety Shape** | Continuous | 0 feet [0 m] |

### 10.3.4.3 FLARE RATE

A barrier may be introduced by offsetting the beginning of the installation farther away from the traveled way than the normal offset. This allows the terminal section to be located farther away, minimizes the driver's reaction to having an obstacle close to the road, transitions the barrier to an obstacle nearer the roadway or reduces the total length of barrier needed.

There are disadvantages to flaring barriers. The greater the flare rate, the higher angle at which a barrier can be hit increasing the severity of crashes. A flared installation may increase the possibly of a vehicle being redirected back into or across the roadway.

The suggested flare rates for barrier design are shown in Table 5.7 of the *Roadside Design Guide.*

### 10.3.4.4 LENGTH OF NEED

The length of need *(X)* depends on the runout length *($L_R$)*, the lateral extent of the area of concern (hazard) *($L_A$)*, the flare rate for the tapered section *(b/a)* and the distance from the edge of traveled way to the face of barrier *($L_2$)*. Guardrail is normally placed 1-foot (0.3 m), or more, beyond the shoulder. The runout length *($L_R$)* is the theoretical distance needed from the edge of traveled way to the hazard measured along the edge of the pavement. The lateral extent ($L_A$) of the hazard is measured perpendicularly from the edge of the traveled way to the far side of the hazard or to the clear zone. The variables are shown in Figure 10-3**.** The tangent length of barrier immediately upstream from the area of concern, $L_1$, is a variable length selected by the designer. Runout lengths *($L_R$)* for the various design speeds and traffic volumes are shown in Table 5.8 of the *Roadside Design Guide.*

The total length of barrier, without the end treatment, can be calculated with the following equation:

$$X = \frac{L_A + (b/a)(L_1) - L_2}{(b/a) + (L_A / L_R)}$$

Where,

$L_A$ = the perpendicular distance from the edge of the traveled way to the far side of the hazard, if the hazard is a fixed object or to the outside edge of the clear zone.

$L_2$ = the distance from the edge of traveled way to the face of the barrier at the location where the rail is parallel to the roadway.

$b/a$ = the flare rate.

$L_1$ = the length of the tangent section ahead of the hazard.

$L_3$ = edge of traveled way to front of hazard. $L_3$ equals, as a minimum, the shoulder width plus the 2 ft [0.6 m] offset for the barrier plus the allowance for dynamic deflection.

Note that for a parallel installation, i.e., no flare rate, the equation reduces to:

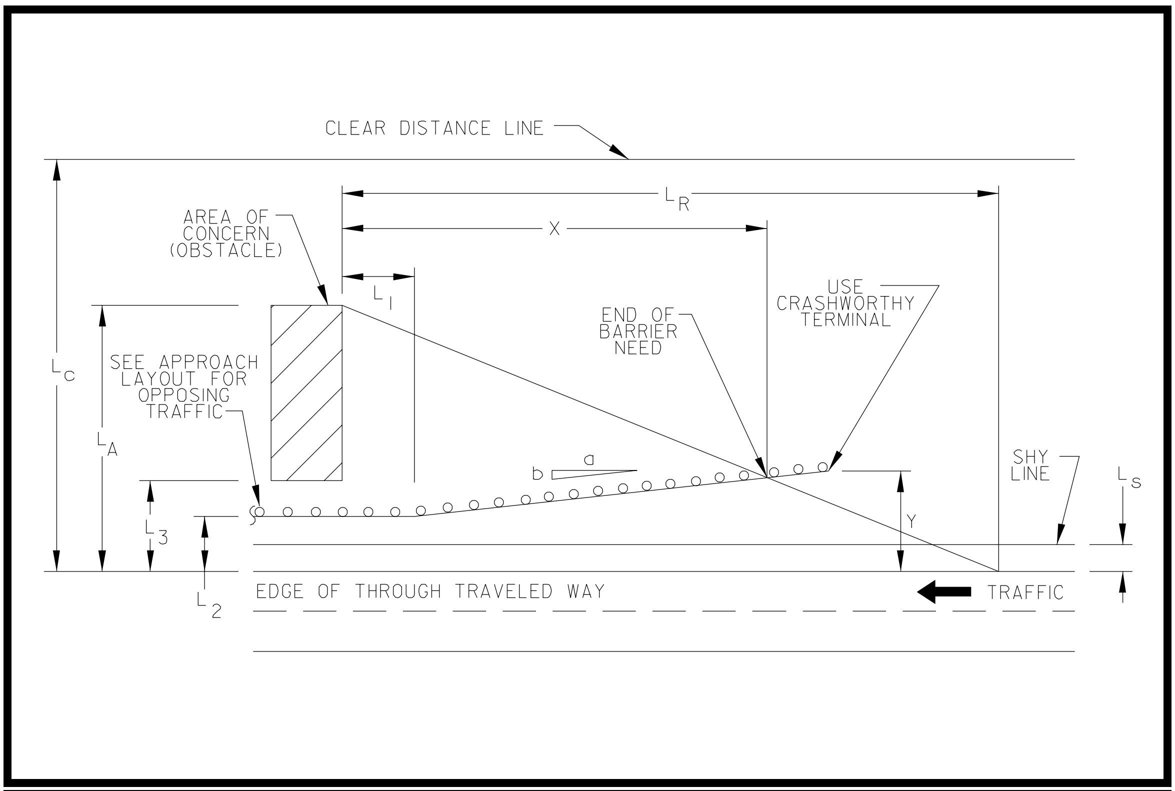
$$X = \frac{L_A - L_2}{L_A / L_R}$$

The lateral offset, Y, from the edge of the traveled way to the beginning of the length of need, can be calculated using the following equation:

$$Y = L_A - \frac{L_A}{L_R}(X)$$

The value of $L_1$, the length of the tangent section ahead of the hazard, is a variable length selected by the designer. If a semi-rigid railing is connected to a rigid barrier, the tangent length should be at least as long as the transition section. This reduces the possibility of pocketing at the transition and to increase the likelihood of smooth redirection if the guardrail is struck immediately adjacent to the rigid barrier. To determine the length of the transition section, see the Department's Standard Construction Details.

***Figure 10-3***
***Approach Barrier Layout Variables***



The final variable for determining the required length of guardrail is the flare rate. Suggested flare rates for various design speeds are shown in Table 5.7 of the *Roadside Design Guide.*

Slopes must be 10:1 or flatter in front of the barrier. It is desirable to place a barrier as far from the edge of the traveled way as possible. Because this may involve a combination of different slope rates, the designer should refer to the *Roadside Design Guide* for proper section and slope treatment.

The shy line offset ($L_s$) is the distance beyond which a roadside object will be perceived as non-hazardous and does not result in motorists reducing speed or changing vehicle positions on the roadway. This distance varies for different design speeds as indicated in Table 5.5 of the *Roadside Design Guide.* If possible, a roadside barrier should be placed beyond (outside) the shy line offset, particularly for relatively short or isolated installations. For long, continuous runs of barrier this offset distance is not as critical, especially if the barrier is first introduced beyond the shy line offset and gradually transitioned closer to the roadway. Note that flatter flare rates are suggested when the barrier must be placed inside the shy line.

The lengths of barriers can be determined by plotting the barrier layout directly on the plan sheets. By selecting an appropriate runout length and the lateral distance to be shielded, the designer can develop a guardrail installation that satisfies all placement criteria.

This method is most appropriate for determining the length of barrier needed to shield embankments or hazards on curved sections of roadways. It should be noted that the portion of the acceptable end treatment that has full effectiveness can be included in the length of need, (*X)*. The *Roadside Design Guide* provides several figures and examples of procedures for determining the length of need for typical situations.

**10.3.4.5 APPROACH BARRIERS FOR OPPOSING TRAFFIC**

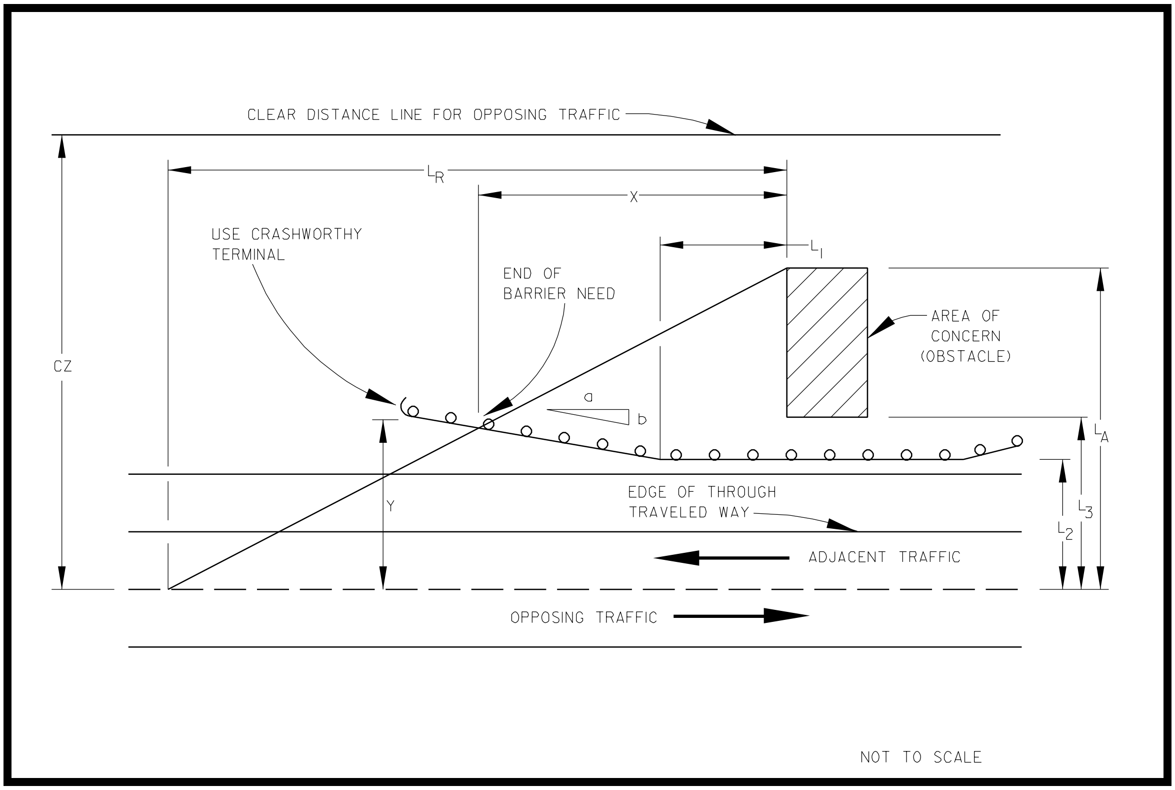
On roadways with two-way traffic, the length of need must be checked from both directions. All lateral dimensions for opposing traffic would then be measured from the centerline of the roadway. Figure 10-4 illustrates the layout variables for an approach barrier for opposing traffic. The length of need and the end of the barrier are determined in the same manner as previously described.

**10.3.4.6 ROADSIDE SLOPES FOR APPROACH BARRIERS**

The embankment where the flared section is to be placed should have a slope of 10:1 or flatter to prevent errant vehicles from striking the barrier either too high or too low for the barrier to be effective. If the slope is steeper than 10:1, the slope should be flattened so that the embankment criterion is not violated. See Figure 5.28 of the *Roadside Design Guide* for the suggested roadside slopes for approach barriers.

Details of typical guardrail installations at bridge ends are shown in the Department's Standard Construction Details. These sheets also show various applications of guardrail installations.

***Figure 10-4***
***Approach Barrier Layout for Opposing Traffic***




## 10.3.5 MEDIAN BARRIERS

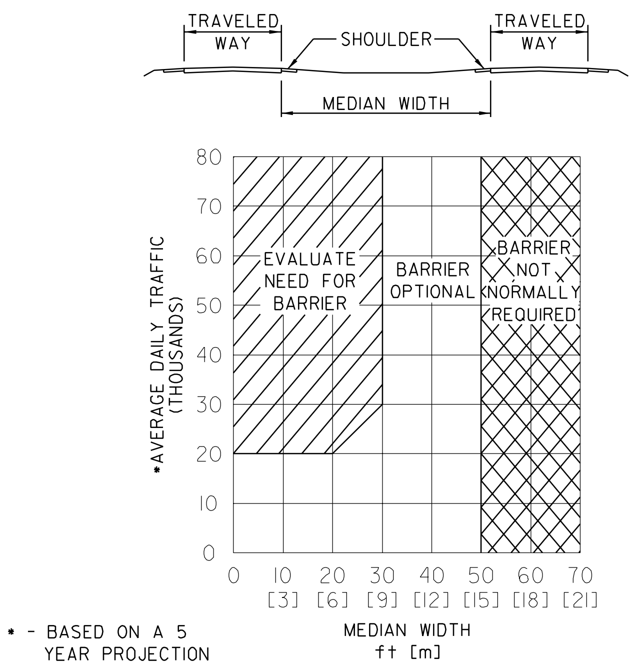
The basic function of median barriers is to prevent out-of-control vehicles from crossing the median and entering opposing lanes. Effective median barriers should be installed on all high-volume, high-speed divided highways with medians where engineering studies establish a need. Figure 10-5 suggests warrants for median barriers on high-speed divided highways that have relatively flat, traversable medians. These criteria are based on a limited analysis of median crossover accidents and research studies and are suggested for use in the absence of site-specific data.

On divided highways, obstacles in the median should be treated the same as obstacles outside the roadway. If the slope is traversable and there are no other obstacles, guardrails on the exit side can be terminated opposite the hazard with a standard guardrail terminal. It need not be flared or have crashworthy end treatment unless it is in, or close to, the clear zone for traffic in the opposing lanes.

Barriers are typically considered for combinations of average daily traffic (ADT) and median widths that fall within the darkened area. In the "Barrier Optional" and "Barrier Not Normally Considered" area of Figure 10-5, a barrier is warranted only if there has been a history of cross-median accidents. When designing for the installation of a median barrier the median must be at least 10 ft [3 m] wide to provide adequate horizontal clearance between the barrier and the edges of traffic lanes.

The most common types of median barriers used in Delaware are the blocked-out W-beam guardrail and the concrete safety barrier. Concrete safety barrier is preferred in narrow medians where regular maintenance is difficult, or where deflection of the barrier would affect opposing traffic. Temporary concrete median barriers are used for traffic control in construction areas. They are placed to separate opposing lanes of traffic on detours and to separate work areas from traffic.

***Figure 10-5***
***Median Barrier Warrants for High-Speed Divided Highways***




## 10.3.6 IMPACT ATTENUATORS

Impact attenuators or crash cushions are designed to prevent vehicles from impacting a fixed object by redirecting a vehicle if impacted from the side and stopping the vehicle at a rate of deceleration that is tolerable to the vehicle occupants when impacting head-on. The two most commonly used concepts used are absorption of the kinetic energy or transfer of momentum.

When designing new facilities the need for these devices should be limited to gore areas, principally on elevated structures at ramp exits.. For other projects they may be the most logical choice to shield the ends of median barriers or longitudinal barriers without crashworthy end terminals. Impact attenuators must be properly installed to provide the desired performance. The approach grading must be flat and the attenuator placed level with the approach ground.

The type of the impact attenuator depends on the expected impact speed and width of the fixed obstacle. Manufacturers provide charts that can be used to determine the appropriate device for the specific location.

The selection of a particular impact attenuator depends on several factors including cost, site compatibility, periodic maintenance needs, extent and ease of maintenance after impact, anticipated performance characteristics, and structural effect of impacts. For additional information and guidance, including the design of the size of the device for the proposed impact speed, refer to Chapter Eight in AASHTO's *Roadside Design Guide* and the manufacturer's literature. It should be emphasized that in frequent impact locations the impact attenuator should be delineated to reduce the number of hits. At these locations a cost/benefit analysis may justify the additional expenditure for the installation of a self restoring attenuator.

## 10.4 CURBS

Curbs serve a variety of positive functions including drainage control, roadside delineation, reduction in right-of-way needs, aesthetics, reduction in maintenance operations, protection of pedestrian traffic, and control of existing and future roadside development. Even with all of these positive attributes, a curb remains a longitudinal fixed object that can cause loss of control and vaulting of errant vehicles. Therefore, curbs must be used sparingly and only after careful evaluation of other alternatives. In most cases, a curb is to be used only on urban facilities with limited right-of-way.

### 10.4.1 TYPES OF CURB

Curbs are described as either barrier or mountable. A barrier curb is any curb with a total vertical rise greater than 6 inches [150 mm] no matter what face or overall shape it may have. Therefore, mountable curbs are those with a vertical rise of 6 inches [150 mm] or less. Both barrier and mountable curbs may have a variety of cross sections. The Department's Standard Construction Details should be used in making the appropriate selection for the function to be served.

### 10.4.2 PLACEMENT OF CURB

The placement of curb has very serious effects on the behavior of drivers and vehicles. As indicated before, the vehicle can become uncontrollable and may even become airborne when a curb is hit. On rural facilities, the use of curb should be limited to channelization and delineation at intersections, crossovers, and entrances. On rural highways mountable type curb is preferred. On urban highways, curb use, while not preferred, is very common. On urban highways, mountable curb should be used for design speeds 50 mph [80 km/h] and above. Barrier curb may be used with design speeds of 45 mph [70 km/h] or less.

The typical effect on most drivers is to shy away from a curb because it is perceived as a danger and visually restricts the travel lane width. This poses the danger of vehicles shying into adjacent lanes. Barrier curbs should be offset 2 ft [0.6 m] from travel lanes and mountable curb offset 1 ft [0.3 m] to minimize this effect. The introduction of curb in itself poses a possible serious hazard and distraction to the driver. Newly introduced curbs should be offset and flared at least 2 ft [0.6 m] beyond the normal offset. In addition, the forward edge (facing traffic) of barrier curb should be gradually depressed at a 12:1 ratio until flush with the pavement or adjacent area. This type of installation will provide a safe end treatment for the driver and not interfere with snow plowing operations.

Curbs used for island channelization should be mountable and offset from the required pavement width by 1 ft [0.3 m]. The islands are to be located in order that they will not, in any way, restrict the travel lane or shoulder area.

The use of guardrail/curb combination should be discouraged where high-speed, high-angle impacts are likely. Where guardrail is used in conjunction with curb, the following shall be adhered to:

1. For design speeds 50 mph [80 km/h] or greater, guardrail shall be offset 10 ft [3 m] minimum from the front face of curb to the front face of guardrail.

2. For design speeds of less than 50 mph [80 km/h], guardrail shall be offset 6 ft [1.8 m] minimum from the front face of curb to the front face of guardrail.

3. Curb height shall be a maximum of 4 inches [100 mm] when curb is placed at the face of guardrail for all design speeds.

#### 10.4.2.1 CURBS AT DEVELOPMENT ENTRANCES

If it is deemed necessary that a center island must be built, then the island should have mountable curb at a development entrance. Curb used in developments should be transitioned to the appropriate type of curb at the radius point where joining state right-of-way. The Department's manuals entitled *Standards and Regulations for Access to State Highways* and *Rules and Regulations for Subdivision Streets* should be referred to in making curb use determination.

#### 10.4.2.2 CURBS AT COMMERCIAL ENTRANCES

The Department's *Standards and Regulations for Access to State Highways* and *Rules and Regulations for Subdivision Streets* manuals should be referred to for detailed information on commercial entrance design. Commercial entrance designs are to be coordinated with the Subdivision Section. In general, due to traffic volumes, it is normally desirable to have a curbed center island of the proper length at commercial entrances to separate traffic movements. The use of center islands will ensure that parking spaces or other internal traffic configurations will not be placed too close to the intersection with the state route. Allowing internal movements close to the main roadway could cause queuing onto the main roadway and substantial reduction in the operational efficiency of both the entrance and the roadway. The center-island should be built with mountable curb. The entrance radii and curb sections parallel to the state road should conform to those on the state road. Barrier curb should be used adjacent to sidewalks. The use or introduction of barrier curb adjacent to the higher-speed roadway is not recommended unless design consideration necessitates such use. For more detailed information see the Department's manuals entitled *Standards and Regulations for Access to State Highways* and *Rules and Regulations for Subdivision Streets.*

### 10.4.3 ACCESS FOR THE DISABLED

For the disabled, it is the policy of the Department to provide accessible curb cuts and adjoining sidewalks at all crosswalk locations and at existing or planned mass transit service locations. The access consists of depressed ramps through curbs suitable for baby strollers, walkers, wheelchairs, etc. Such ramps are also to be provided in refuge islands where a crosswalk crosses a channelized island. Typical details of curb ramps are shown in the Department's Standard Construction Details.

## 10.5 RIGHT-OF-WAY

The designer is responsible for defining the limits of right-of-way necessary to construct, operate, and maintain the highway project. The following discussion is general in nature and the designer is to refer to Project Development Manual, for a detailed description for preparing right-of-way plans. In designing the project right of way, the designer must first identify actual construction limits from the cross sections to define the toe of fills or the top of cuts.

Second, the designer must identify, through input from the Utilities Section, the reasonable real property needs of public or municipal utilities required to relocate facilities as a result of the proposed project.

When right of way needs are being defined, space for current and future bus stop improvements should be considered. Depending on the type of improvement to be installed, a width of up to 14 ft [4.3 m] may be needed (measured from back of curb). The minimum right-of-way needed at each stop whether existing or proposed is 8 ft [2.4 m].

The right of way limits should be of consistent width and wide enough to accommodate the construction limits and appropriate border areas necessary for ditching, utilities, and their maintenance. In urban or other highly developed areas where open ditching is inappropriate, desirable right-of-way border areas should be minimized to reduce negative impact on adjoining private property.

To minimize right-of-way design time and avoid plan changes, the designer should consult with personnel from the design support sections early in the design process, preferably at an on-site scoping meeting before completing the preliminary plans.

### 10.5.1 RIGHT-OF-WAY CONFIGURATION

Generally, right-of-way lines should be designed with as few breaks and changes as possible. The following general criteria should apply:

- Where there is need for a width change close to the P.C. or P.T. of a horizontal curve, the breaks should be made coincident with the P.C. or P.T. if possible.
- Where there is need for a change of width close to a property line between two different owners, the break in widths should be made at the property line. Where utilities exist or will be located adjacent to the right of way line, the right-of-way should be tapered rather than jogged, if possible. This will ease the installation of utilities along the alignment.
- Where width changes are required both right and left of the roadway, the break points should be made at the same station, if possible.
- Breaks in widths should not occur in drainage channels, roads or drives where installation of right of way monuments would be impractical.
- Where right-of-way may only be needed from a portion of a parcel, consideration should be given to acquiring right of way through the entire parcel for future connecting projects, so that the owner will not have to be contacted again. This determination is made in coordination with other supporting sections.
- Do not define right-of-way lines with spiral curves. Where centerlines follow spiral curves, right-of-way lines should be described using a circular or compound circular curve of similar shape.
- Proposed right-of-way lines must be described in order for surveyors to lay them out in the field. Dimensions showing survey stations and pluses with offset distance right or left of construction centerline are required in addition to coordinates, bearings and distances.

### 10.5.2 EASEMENTS

Under certain conditions it is preferable to obtain an easement rather than to purchase right-of-way. There are two types of easements: (1) temporary and (2) permanent easements. The type of easement should be identified on the plans.

A temporary easement should be obtained where it is not necessary to obtain permanent possession of the land or permanent right of access to the land. Temporary easements are appropriate:

- For any areas where the Department will have no maintenance responsibility after the completion of the proposed project construction;
- Where relatively flat cut or fill slopes extend beyond the right-of-way line and the lateral clear zone or for grading purposes that may benefit the property;
- To obtain proper grade on private driveways and approaches;
- For channel changes and inlet and outlet ditches at drainage structures where future maintenance is not anticipated; and
- For construction working areas.

A permanent easement should be obtained where it is not necessary that the State own the land, but where perpetual interest is necessary. Examples are where the Department needs to access the property for future maintenance, repair, or replacement of the highway facility, its drainage systems or appurtenances and as provided for in a project's right of way or railroad agreement.

### 10.5.3 RIGHT-OF-WAY MONUMENTS

Right-of-way monuments may be placed to provide a permanent reference for re-establishing the centerline and right-of-way line. Right of way monuments should be located and punched so the center is on the right of way line. Details of a standard right-of-way monument are shown in the Department's Standard Construction Details.

## 10.6 FENCING

It is Department policy that installation of fences should normally be considered under one or more of the following conditions:

- For access restrictions on interstate or other designated controlled access highways,
- Replacement fence where an existing fence was removed because of right-of-way widening, or
- For locations where there is a documented need for fencing i.e. pedestrian and bicyclist safety or right-of-way negotiations.

The location of fencing depends on who will assume the ownership and maintenance responsibility, 1 ft [0.3 m] inside the right of way for DelDOT and 1 ft [0.3 m] outside if by others. The responsibility for installing fencing varies. Fencing required for DelDOT purposes will normally be shown on the contract plans and included as a bid item for the contractor. The type of fencing will depend on the characteristics and use of the adjacent property.

Installation of replacement fencing or new fencing as the result of negotiating easements or property takings are normally included in the right-of-way settlement agreement. This agreement provides for the affected property owner to be responsible for construction and maintenance of any new fence, with installation reimbursement by the State. Occasionally, the right-of-way agreement will specify that this fencing be included as a contract item. Locations and quantities of fencing to be constructed in this manner are determined by Real Estate and coordinated with the designer.

## 10.7 UTILITY ADJUSTMENTS

This section is a general discussion of a project's relationship with utilities. The specific details are covered in Chapter 11, Plan Development. In addition, the Department has published the *Utilities Design Manual*, which clearly sets forth policies and procedures regarding the relationships among the Department, the public, and private utilities in Delaware. Much of the manual is related to the accommodation of utilities within the highway right-of-way and adjustments initiated by the utilities. Other sections define responsibilities and procedures related to needed utility adjustments resulting from proposed highway improvement projects. It is this second category that is of concern to designers.

In storm drain design, it is often possible to avoid conflicts with underground utilities by making minor adjustments in the line or grade of the storm drain. The designer should consider conflicts with any utility in making the final design to minimize relocations and conflicts. Relocations of utilities frequently delay the progress of construction and so should be avoided where possible. As further described in the manual, costs for relocating and adjusting utilities may either be the affected utility's or the Department's responsibility. The designer needs to recognize that no matter which party is responsible, the cost will be directly or indirectly passed on to the user.

The procedures and responsibilities for utilities adjustments set forth in the *Utilities Design Manual* are briefly summarized below in terms of the four phases of plan development.

### 10.7.1 SURVEY PLANS

The designer prepares survey plans showing the approximate project limits, existing detail, and project number(s) assigned to the project. Two sets of survey plans are provided for each utility and are transmitted by the Utilities Section.

The Utilities Section returns marked-up plans showing complete information on existing and abandoned facilities in the area. The information provided includes whether the facilities are aerial, surface or underground, sizes of pipes, numbers of conduits, approximate depths, and any private or commercial easements.

### 10.7.2 PRELIMINARY PLANS

The designer prepares preliminary plans showing the proposed alignment, profile, drainage, signal pole location, clear zones, right-of-way taking, existing utilities from survey plan data and other details. Two sets of plans are submitted by the Utilities Section to each potentially affected utility company, who reviews these plans and returns them showing their proposed work plan.

The designer, assigned utility coordinator and, in some cases, the utility company's representative review these plans to determine if the exact horizontal and vertical location of certain facilities are an important part of the design considerations. Where major conflicts with underground utilities appear possible, the Utilities Section arranges for determining the exact field location of the existing underground installations, typically with taking test pits. The Utilities Section submits this information to the designer. The designer and utility coordinator determine which underground or aerial conflicts cannot be avoided and discuss alternatives with the affected utility company. It is very important that the potential impact on scheduling, current project estimate and the responsibility for preparing the design plans and quantities as well as the actual construction be identified at this time.

### 10.7.3 SEMI-FINAL PLANS

Semi-final plans are prepared showing the final centerline, profile, drainage, right of way and other details.

Two sets of semi-final plans for each utility are provided to the Utilities Section. These plans are delivered to each affected utility. A representative of the Utilities Section coordinates a review of the project's affect on each utility's facilities.

The utilities plot their proposed underground relocation work on the plans, and the information is returned to the designer through the Utilities Section. The Utilities Section arranges with the utility for any needed relocation work and formal agreements. The scope and schedule for the work is included in the project's utility statement that is furnished to the designer for preparation of the P. S. and E. package.

### 10.7.4 P. S. AND E. PLANS

When the final plans are completed and the project is advertised, one set of final plans is forwarded to each utility. If it has not previously been notified to start the adjustment, the utility is directed by letter from the Utilities Section to order materials and begin making the changes or alterations to their facilities.

## 10.8 SIDEWALKS

### 10.8.1. GOALS AND OBJECTIVES

Sidewalks are an integral part of the Department's transportation infrastructure program. They facilitate and encourage safe and convenient pedestrian travel within communities and among different land uses. They provide safe and reasonable access to public transportation and other alternative modes of transportation, thereby helping alleviate vehicular traffic and reduce emissions. They also reinforce the Americans with Disabilities Act (ADA) by increasing the access opportunity for mobility impaired individuals.

The incorporation of sidewalks and pedestrian amenities also provides better land use and transportation connections, thus encouraging more trips on foot, improve access to transit, improving access to adjacent land uses and communities, conserving energy, and enhancing the Department's vision for multi-modal and inter-modal transportation systems.

In addition, by providing this transportation option, the installation of sidewalks can be an effective means in reducing automobile dependence and use. It will assist Delaware's mission toward cleaner air under the requirements of the Clean Air Act Amendments of 1990.

With the addition and installation of proper sidewalks and pedestrian amenities, safety, accessibility, ridership, and more favorable perceptions of public transit service can be increased. Communities will also be able to safely link to other land uses and transportation modes, resulting in better and more desirable neighborhoods and land development practices.

The need for sidewalks in urban or suburban areas is most noticeable at points of community and urban development that result in pedestrian concentrations near or along the state's or municipality's transportation system (roads, rail, air, and water transport facilities). Such examples include: public and private transportation depots, local businesses, industrial receiving and distributing plants, corporate centers, shopping centers, malls, schools, medical centers, religious centers, hotels and places of residence.

The design of sidewalks should reflect the community or context in which they are to be placed through the choice of materials or proximity to a traveled way. Buffer zones between curb and sidewalk are preferred to enhance pedestrian perception of safety and convenience.

It is the Department's goal to ensure that all efforts have been undertaken in determining the need and justification for installing, reconstructing, improving, requiring, or extending sidewalks for its transportation projects as well as for other initiating parties in public or private development.

### 10.8.2 REGULATORY REQUIREMENTS

The specific state law that governs the installation of sidewalks is Title 17, Section 132(f), of the Delaware Code. In essence, the Department is to reconstruct disturbed sidewalks or install new sidewalks when constructing in an urbanized area, if there is a demonstrated present need or a reasonably anticipated future need. The Project Development Process determines whether such need for sidewalks does or will exist for all or any part of a project. Before arriving at a decision as to the need for sidewalk construction, the Department consults with the affected county planning department, Department of Education and the local school district. Within incorporated municipalities, the Department has a town/city maintenance agreement in force that should be reviewed as to its affect on the decision to reconstruct or install sidewalks.

Since the original law was enacted, additional requirements have been initiated that affect the decision making process on when and where to construct sidewalks, the design and construction standards, and the review and field inspection procedure. The need for and encouraging the use of sidewalks are important parts of the Americans with Disabilities Act, the Clean Air Act, federal legislation funding transportation programs and the State's Long-Range Plan for Transportation. Sidewalks shall be determined as part of the Department's Project Development Process and scoped as part of the handoff prior to design initiation.

The interest of the disabled on state and federally funded projects are represented by the State's Architectural Accessibility Board. This board adopts standards and criteria to address service and accessibility for the disabled and handicapped and is the regulatory agency for ensuring compliance with all applicable standards and criteria during design and in construction.

The Department applies accessibility standards during the design and construction of transportation facilities based on project initiation, scope, and funding authorization. As a part of the initiation process, sidewalk facilities and connector points for new sidewalks, at, along, or between a community's public roadways and transit service are also considered to ensure that the elderly, disabled, and handicapped have access and use of our highway and transit facilities. The Project Design Checklist provides guidance for submission of plans to the Architectural Accessibility Board for review.

The appropriate guides to ensure conformance include: the current State of

Delaware Architectural Accessibility Standards; Part II of the Federal Register's Architectural and Transportation Barriers and Compliance Board (36 CFR Part 1191) - dated July 26, 1991; and Part IV of the Federal Register's Department of Transportation (49 CFR Parts 27, 37, 38) - dated September 6, 1991.

**10.8.3 DESIGN APPROACH**

Determining the need for sidewalks is a standard component of the Department's process to plan, design, construct, and reconstruct transportation projects and all multi-modal and inter-modal networks.

During the project development process, all projects are evaluated for consideration of the removal and/or relocation of roadside appurtenances, street furniture, vegetation, mailbox posts, landscaping, public or private utilities, poles, guardrail, and/or traffic signs in order to satisfy and encourage safe pedestrian movement. The installation of any obstruction directly within a sidewalk buffer strip (area between edge of curb or shoulder and edge of sidewalk facility) which prohibits or blocks safe pedestrian movement should be avoided. If prohibitive objects are placed directly within/along a sidewalk location, consideration should be given to relocating or repositioning that conflicting sidewalk section.

Certain circumstances such as geographic design, engineering, environmental, safety constraints, or the extent and scope of the project itself, may require sidewalks to be constructed along one side of a roadway, transit corridor, or land use area. For the most part, transportation projects involving a roadway or transit corridor should have sidewalks on both sides. Sidewalks may be omitted on one side of the street where that side clearly cannot be developed and where there are no existing or anticipated uses that would generate pedestrian trips on that side.

Because of legal and design criteria differences, sidewalks are not to be designed, signed, and accommodated for other than pedestrian use. Therefore, a sidewalk/pedestrian facility should not be identified, signed, or striped for some other transportation or recreational use (such as a bicycle). If shared facilities (such as both pedestrian and bike use) are desired, policies and design guidelines reflective of the joint use shall be followed.

The incorporation of sidewalks should be consistent with all other state, county, city, and/or town sidewalk policies, ordinances, or mandates, including the Department's Long-Range Transportation Plan. The Department's Division of Planning will ensure sidewalk provisions and requirements are coordinated with other transportation and land use projects in the state.

Future maintenance responsibility for sidewalks is an important consideration and should be clearly defined before installation.

**10.8.4 GUIDELINES FOR ASSESSING THE NEED AND CRITERIA**

Sidewalks are considered during the project development phase when evaluating a roadway or transit facility for construction, reconstruction or rehabilitation. The Department, another party or a different agency, regardless of any roadway or transit improvement may initiate sidewalks as independent projects. Therefore, sidewalks should be considered for all Department transportation networks unless it is specifically determined that:

- Sidewalk construction conflicts with public safety.

- Sidewalk cost and economic impact of construction is prohibitive in relation to the need, the benefits realized, or their probable use.

- Specific land use factors indicate there is no current or future need for sidewalk.

During the planning and project initiation phase, facilities for pedestrian movement warranting sidewalk are considered for their impacts on project costs, right-of-way needs, additional environmental constraints, highway or bridge geometrics/standards, and public and legislative input. When planning, initiating, or recommending the location or relocation of transit service, the Department considers installing sidewalks as well as other forms of pedestrian accommodations to address safety and accessibility. More specifically, the location and environmental study report identifies the initial need for the construction, reconstruction, improvement, or extension of sidewalks.

When pedestrian facilities are provided, special needs of the young, elderly, disabled, and handicapped are to be considered. This may include extending a project's limits for reasonable distances to accommodate better access and safety.

Within the context of multi-modal and inter-modal systems (i.e. linking various land uses and destinations with accessible transportation systems), the location and provisional extent of pedestrian facilities are studied to logically connect their termini.

During the project development process, several agencies, and departments are involved ensuring reasonable consideration of pedestrian needs are met. Where appropriate, these groups help assist in identifying, justifying, securing funding and determining the extent of the sidewalk and pedestrian amenities.

Representatives from the Department of Transportation include the Bicycle and Pedestrian Coordinator, the appropriate District Engineer, the Traffic Engineering and Management Section and the Delaware Transit Corporation. Representatives from outside DelDOT include the Architectural Accessibility Board, county and local planning agencies, the appropriate Metropolitan Planning Organization, the local school district affected by the project, and the Department of Education Transportation Supervisor.

The public and other entities involved in pedestrian and transportation safety may identify and suggest sidewalk and pedestrian accommodations. This is usually realized during or after a project's public workshop/hearing. The local citizenry may also identify problems overlooked.

Projects being initiated or reviewed by the Department consider several factors in determining the appropriateness of constructing, reconstructing, extending, or requiring sidewalks. The following is a discussion of these factors.

Existing and expected land use patterns, growth areas, and generators of pedestrian movements are considered as follows:

- Land use—residential (high/cluster, medium, low), business/commercial, mixed uses, industrial, recreational, educational, agricultural, and open space.

- Growth areas—targeted, expected, or recommended areas of urban growth, usually around corridors of current or planned highway capacity improvements, sewer, or water upgrades.

- Specific generators of pedestrian movement—major employment areas (more than 100 employees), schools, entertainment special events, shopping centers/malls, residential neighborhoods, medical centers, religious centers, colleges and universities, bus stops, depot and transit locations, public and private parking garages/facilities, parks and recreational areas.

- Whether or not the Department, county, city, municipality, or other public or private organization plans on some type of capital improvement involving transportation infrastructure.

Existing and anticipated pedestrian characteristics are analyzed including:

- Special user groups—children, adolescents, elderly, disabled, handicapped, commuters, and those dependent upon or utilizing public transit.

- Trip purpose—shopping errands, commuting to school, work, or place of destination, visiting friends, recreational/entertainment, child care, vacation.

- Frequency of use—daily, weekends, seasonal, as needed.

- Other factors—weather conditions with season, time of day, holidays, school and college schedules, safety, convenience, transit routes.

Existing site characteristics affecting pedestrian use are reviewed including available parking (free, metered, hourly, monthly), roadway surface condition, shoulders, pavement markings, crosswalks, street lighting, phased signals, type of transit accommodation, accessibility to destination, access control, intersection links, safety factors, location of signs, channelization, slopes, and drainage.

An analysis of current or proposed land uses along or near a roadway corridor is made to determine if there is a failure to provide or include a design that incorporates sidewalks and pedestrian amenities. The effect of adding new sidewalks in the area is reviewed to ensure user safety. Environmental constraints such as wetlands, floodplain, steep slopes, historical properties or archaeology, hazardous contamination sites, rare or endangered species and farmlands are considered.

A final consideration is whether or not an intersection, roadway or transit corridor, subdivision or land use area can be effectively redesigned or retrofitted with sidewalks and pedestrian facilities.

Information not readily available can be obtained through the following methods:

- Observation,

- Discussion with local governments, planning groups, property owners, civic organizations, and task forces,

- Public information meetings/brochures,

- Accident reports,

- Questionnaires,

- Architectural Accessibility Board,

- Local School Districts,

- Delaware Bicycle Council,

- DNREC's Parks and Recreation, Soil and Water, Technical Services, and Air and Waste Management sections,

- State Historic Preservation Office, or

- Soil Conservation Service-U.S.D.A.

### 10.8.5 WARRANTS

Warrants based on pedestrian volume have not been established for sidewalks. Actual volumes counted at any one time may not reflect the demand for pedestrian use. Factors such as poor existing facilities (which discourage use), weather conditions, school schedules, holidays, proposed land use changes, growth areas, proximity of transit and depot locations/stops, and other factors affect current pedestrian use. Therefore, many of the benefits from the construction, reconstruction, or the extension of sidewalks and pedestrian facilities are not quantifiable with the actual magnitude of the safety benefit unknown. This is partially because individuals tend to walk where there are sidewalks and sidewalks tend to be installed where people are walking. In addition, pedestrian use and volumes are not regularly collected by planning and transportation agencies and cannot be easily forecasted, modeled or predicted.

The need for sidewalks should be related to the functional classification of streets. For example, collector streets are more likely to have greater pedestrian use and volumes than residential streets. Collector streets are normally used by pedestrians to access public transit, commercial developments or other various land uses on the arterial to which they feed. Sidewalks should definitely be provided along developed frontages of arterial streets in land use zones that promote pedestrian activity.

Sidewalks should be considered whenever there is regular or periodic pedestrian travel along an existing roadside, street or transit corridor. Sidewalks should also be considered along any street, highway or transit corridor in developed areas not provided with shoulders even if existing pedestrian activity appears light.

### 10.8.6 DESIGN GUIDANCE FOR SAFE PEDESTRIAN CIRCULATION

Whenever a project is being initiated or planned where pedestrian movement exists or is anticipated, the initial scope and planning involved with the project should provide suitable space within the current or future right-of-way for safe pedestrian circulation. Sidewalks to be financed and maintained by others may also be included in a project.

When there are existing shoulders or walkways intended for pedestrian use, sidewalks should be evaluated at the project development stage for condition, suitable width, continuity, and limits. Where shoulders are being utilized for pedestrian movement, installing a parallel sidewalk may be considered because shoulders must be carried through intersections where turning lanes and pedestrian areas should not be combined.

Deteriorated sidewalks need to be evaluated for rehabilitation or reconstruction and additional width as necessary. Incomplete systems should be considered for connection to new sidewalks and end at logical terminations.

During the subdivision review process often dedicate right-of-way for transportation corridors and/or open space. The dedication of open space may often include areas close to a roadway edge, providing a buffer zone. County sidewalk policies provide for limited pedestrian circulation within a development. The maintenance of such pedestrian facilities becomes the responsibility of the development, local ordinance, adjacent property owner, or governing entity.

Pedestrian and sidewalk projects at intersections or along highway/transit corridors may include design, redesign, or traffic calming measures. These could include tightening of turn radii, channelized islands, medians and curbs, refuge islands, roundabouts, bulbs, neckdowns, signing, striping, transit shelters, and other features.

The extension of project limits beyond related highway or transit improvements for reasonable or short distances may be considered in order to include necessary pedestrian facilities at nearby intersections, provide safe access to public transportation facilities, or to avoid short sidewalk gaps. This decision can be reached anytime during the project development or design stage, and can be adjusted or deleted as needed. The project scope and funding may have to be revised accordingly.

### 10.8.7 PEDESTRIAN ACCIDENT HISTORY

An important factor in defining the need and locating and designing a sidewalk is accident history. The plan development process should include a study to define:

- Where and how did the accident occur: i.e. at an intersection or median, along the road, shoulder or existing sidewalk, off the shoulder, or at a transit accommodation?

- Who was responsible?

- What was the pedestrian's origin and destination?

- What are the normal pedestrian movements in that area?

- Were there any existing pedestrian accommodations, lumination devices, warning signs, safety or traffic control devices, alcohol involvement or other contributing circumstances?

### 10.8.8 EXISTING SITE ACCOMMODATIONS

Typically included in the project development and design process is the assessment of the condition of the existing sidewalk network within the project and adjacent area. This assessment would include:

- The location of existing walkways, shoulders, worn paths, and greenway links;

- The location of incomplete walkway systems that adjoin or are within existing right-of way;

- The condition of existing facilities and how well they function or accommodate pedestrian movement;

- Any limiting geographical or architectural features that enhance or reduce feasibility of constructing pedestrian facilities;

- Any major or minor modifications in road or transit design that may enhance or reduce feasibility of constructing pedestrian facilities;

- Existing transit or depot stops with pedestrian or roadside amenities; and

- Whether surrounding or adjacent residential subdivisions, commercial or business land development, mixed land uses, or other developing land uses have provided or include a design that incorporates sidewalks and pedestrian amenities for school bus stops, greenway or walkway links to other land uses, and transit stop access for safe pedestrian movement and circulation.

### 10.8.9 PLACEMENT

For new sidewalks a minimum width of 5 ft [1.5 m], not including the width of the top of curb, is recommended. For new sidewalks at underpasses or overpasses, a minimum width of 4 ft [1.2 m] is permissible. Wider sidewalks may be required, preferred or required by local ordinance depending upon the volume and nature of two-way pedestrian traffic. Narrower sidewalks may be allowed, but this will be based on surrounding roadside or geographic constraints. Minimum thickness can vary according to materials, but be at least 4 in [100 mm] for Portland Cement Concrete. A minimum thickness of 6 in [150 mm] is required at entrance and driveway areas. A cross slope of 1% is required, but 2% is preferred.

The Department conforms to the Uniform Federal Accessibility Standards (UFAS) when incorporating sidewalk into an overpass or underpass on projects. These standards generally limit maximum ramp and depressed sidewalk grades to 8.33% and include 5 ft [1.5 m] landings every 30 ft [9 m], handrails 32 in [813 mm] in height, and minimum clear widths between handrails of 5 ft [1.5 m] for wheelchairs to pass. The minimum vertical clearance for pedestrian space is 80 in [2 m]. Objects protruding into this space such as signs and utility boxes present a hazard for the visually impaired. All ramp surfaces shall be stable, firm and slip resistant. If pedestrian signals are provided, the push button controls are to be placed in close proximity to the sidewalk for ease of operation by wheelchair users.

At intersections, paired perpendicular curb ramps are preferred because they allow the wheelchair user to enter the crosswalk perpendicular to the travel lane. Single ramps may be used in exceptional circumstances, however, the designer should understand that the wheelchair user will be placed at risk if crosswalk striping and visibility are not carefully considered.

Curb ramps should be sited and oriented to achieve maximum visibility and orientation to the pedestrian path of travel. Driveway entrances should be designed to minimize excessive cross slopes. When a turn must be made to enter or exit a ramp, level landings at the top and bottom of ramps of 5 ft [1.5 m] are preferred, 4 ft [1.2 m] minimum.

Small planting strips between the sidewalk and curb may not be practical unless the property owners, civic associations or volunteer programs can make provisions for maintenance. For increased user safety, sidewalks should be as far away from travel lanes as practical. Where possible a buffer width of at least 3 ft [0.9] m between the edge of a sidewalk and the edge of a shoulder, curb, or traveled way is preferred. A 3 feet [0.9 m] wide strip would improve safety, driver comfort, and provide an area for snow removal and mailbox posts.

In central business districts, commercial areas, apartment complexes and generally where buildings or parking areas lie near or on the right-of-way, consideration should be given to pave the entire width from curb to building, property, or right-of-way line. The minimum desirable width of sidewalk between curb line and building face is 8 ft [2.4 m]. This permits space for utilities and other roadside appurtenances, and limited snow.

Standard material for any sidewalk or walkway is usually Portland Cement Concrete. However, sidewalk or walkway materials are not limited to Portland Cement Concrete. Upon approval and when funding is available, more aesthetic materials such as brick, asphalt, or other stable, firm, slip-resistant material surfaces may be used. This may be appropriate for traffic calming areas and in certain circumstances to address the concerns expressed by land use planners and/or communities that concrete sidewalks are aesthetically unpleasing.

When constructing, reconstructing, or extending sidewalks at or near intersections, the design should consider enhancing accommodations for pedestrians and vehicles throughout the intersection. Such elements may include refuge islands, signs prohibiting turn on red, separate pedestrian signal indications and phases (with pedestrian button in close proximity to the sidewalk) and offset room for traffic signs/poles and utilities.

In establishing the location of sidewalks, consideration will also be given to the need for or relocation of conflicting drainage facilities, sideslopes, new traffic control and signing devices, intersection crossovers, striping, utility appurtenances, mailboxes with posts and transit stops.

### 10.8.10 MAINTENANCE RESPONSIBILITY

As a policy the Department of Transportation does not normally maintain sidewalks. Depending upon their location, applicable laws, local ordinances and the current town or city maintenance agreement, sidewalks are the maintenance and upgrade responsibilities of the property owner, homeowner's association, municipality, town, city, suburban or non-suburban area, incorporated or unincorporated area, or governing body which bears jurisdiction. Delaware Transportation Corporation usually contracts out maintenance of sidewalks and other passenger amenities immediately adjacent to transit facilities.

Projects involving pedestrian or sidewalk amenities proposed under the Transportation Enhancement program have a formal agreement with the responsible party that includes a description of maintenance standards to be upheld and assigns the responsibility for the associated costs for those amenities. Maintaining a pedestrian or sidewalk facility involves several items including snow removal, trash and debris removal, control of vegetation, reconstruction, graffiti removal, resigning or re-striping (specifically related to the sidewalk), avoiding general neglect and deterioration for whatever cause and alterations of the surface or subsurface level required to improve the appearance.

Projects under the Suburban Streets and Resurfacing Program may include repairs, replacement or general maintenance to existing deteriorated sidewalks. For all new construction and replacement, accessibility guidelines and standards are to be followed.

The Department of Transportation repairs or replaces any existing sidewalk surface that has been damaged or altered by the Department or its contractors. Repair or replacement of sidewalks follows all accessibility guidelines and standards.

## 10.8.11 REMINDERS

When sidewalks are proposed or initiated without a formal agreement to the contrary, the Department may not assume any maintenance responsibility.

Although not to be addressed as part of the project, it may be beneficial to consider the need for future sidewalk and reserve the right-of-way.

Delaware's Department of Education does have busing rules affecting the busing rights for children. These may come into play if certain communities and schools are connected with continuous sidewalk access. The most significant affect is that public busing privileges may be revoked.

Local governments or jurisdictions may adopt land use or subdivision ordinance regulations to protect transportation facilities, corridors, and sites for their identified functions. This could include, but is not limited to, facilities providing safe and convenient pedestrian or bicycle access within and from new subdivisions, planned unit developments, transit stops, greenways, and neighborhood activity centers such as schools, parks, and shopping areas.

If not required under county, city, or local jurisdiction, the Department may request or require sidewalks and pedestrian facilities to be installed prior to subdivision entrance permit approval. The Department may also request the installation of sidewalks and pedestrian facilities along roadway or transit corridors as part of the mitigation plan under a traffic impact study.

As a part of improving the transportation network, the Department initiates and designs sidewalk projects to connect existing and future transit routes, transit facilities, park-and-ride lots, public/private parking areas, bus stops for schools, businesses, shopping centers, industrial parks, residential communities, or any other public or private institution. This enhances multi-modalism while decreasing vehicular traffic and automobile emissions.

### 10.8.12 FUNDING ALTERNATIVES

Although specially defined on the Project Initiation Form, the designer should be aware that the construction, reconstruction, or extension of sidewalks can be funded by several different methods and funding sources.

Projects initiated by the Department are usually 100% funded by the Department and include:

- Removal and replacement of existing sidewalk caused by the construction, reconstruction, improvement, or extension of any highway, transit, safety, or pedestrian related improvement;

- Projects facilitating State or Department transportation purposes. This may include, but is not limited to, improving or expanding transit facilities, walkway/pedestrian corridors, greenway links, or safety improvement projects.

Projects initiated by others for design and/or construction by the Department have various matching fund ratios. These include:

- Projects may be 100% funded under the Suburban Streets and Resurfacing Program for new sidewalk projects that have been approved and initiated by the Department in recognition of meeting the needs of the public, town officials, or other governing bodies.

- Projects may be funded and initiated by a school district or other agency with a 50% match by the Department. These would involve new or reconstructed sidewalks within a project's termini or short distances outside a project area to connect sidewalks to existing pedestrian or transit generators from or to educational facilities.

- Projects may be 100% funded and initiated by a party or agency for removal and replacement of deteriorated sidewalk.

- Projects may be 50% jointly funded by a party or agency for utility adjustments, drainage, signals, pedestrian barriers, retaining walls, crossovers, etc. required solely for sidewalk safety and enhancement. This does not include projects initiated for ADA conformance.

- Projects may be 10% funded by an initiating party or agency, 10% by the Department and 80% funded by the Federal Highway Administration. These projects meet the criteria for funding under the federal Intermodal Transportation Efficiency Act. Qualified applicants can initiate projects to be included in the Department's Transportation Enhancement Program. These projects must first gain approval from the Department's Technical Advisory Board. The projects are then subject to final review and approval by the Secretary of Transportation.

## 10.9 BICYCLE FACILITIES

There is a wide range of facility improvements that can enhance bicycle transportation. Suitable accommodations for bicyclists shall be determined as part of the Department's Project Development Process and scoped as part of the project handoff prior to design initiation. Improvements can be simple involving minimal design considerations such as changing drainage grate inlets, or they can involve a detailed design such as providing a bike path.

Facility improvements for motor vehicles through appropriate planning and design can enhance bicycle travel or should at least avoid adverse impacts on cycling. Unless access is specifically denied, some level of bicycle use can be anticipated on most roadways. All new roadways, except those where bicyclists will be legally prohibited, should be designed and constructed under the assumption that they will be used by bicyclists. Guidelines are presented here to help design and construct roadway improvements and separate facilities that accommodate the operating characteristics of bicycles. Additional information including signing layouts, striping, and design details can be found in AASHTO's *Guide for the Development of Bicycle Facilities.*

Because most highways have not been designed with bicycle travel in mind, there are often many ways in which roadways should be improved to more safely accommodate bicycle traffic. Roadway conditions should be examined and, where necessary, safe drainage inlets, safe railroad crossings and smooth pavements should be provided. Drainage inlets and utility covers are potential problems to bicyclists. When designing a new roadway, these types of appurtenances should be kept out of the bicyclists' expected path.

Parallel bar drainage inlet grates can trap the front wheel of a bicycle causing loss of steering control. Often, the bar spacing is such that it allows narrow bicycle wheels to drop into the grates, resulting in irreparable damage to the bicycle wheel and frame and/or injury to the bicyclist who could be thrown from the bicycle. These grates should be replaced with the bicycle-safe grates in the Department's Standard Construction Details. Parallel bar grates are not to be used where bicycles may be present.

Railroad-highway grade crossings should ideally be at a right angle to the rails. The more the crossing deviates from this ideal crossing angle, the greater is the potential for bicyclists' front wheels to be trapped in the flange way causing loss of steering control. It is also important that the roadway approach be at the same elevation as the rails.

Consideration should be given to the materials of the crossing surface and to the flange way depth and width. If the crossing angle is less than approximately 45 degrees, consideration should be given to widening the outside lane, shoulder, or bicycle lane to allow bicyclists adequate room to cross the tracks at a right angle.

Pavement surface irregularities can do more than cause an unpleasant ride. Gaps between pavement slabs or drop-offs at overlays parallel to the direction of travel can trap a bicycle wheel and cause loss of control; holes and bumps can cause bicyclists to swerve into the path of motor vehicle traffic. Thus, to the extent practicable, pavement surfaces should be free of irregularities and the edge of the pavement should be uniform in width. On older pavements it may be necessary to fill joints, adjust utility covers or, in extreme cases, overlay the pavement to make it suitable for bicycling. Longitudinal joints in pavement and between pavement and gutter pans should not be more than ½ in [12 mm] wide. Longitudinal drop-offs between pavement and gutter pans or between travel lane pavement and shoulder pavement should not exceed ¾ in [18 mm]. Ridges used to create "rumble strips" in pavements should not be more than ¾ in [18 mm] when perpendicular to bicycle travel. Properly located warning signs should precede these locations.

Roadway treatments intended to accommodate bicycle use must address the needs of both experienced and less experienced riders. One solution to this challenge is to develop the concept of a "design cyclist" and adopt a classification system for bicycle users such as the following:

<u>Group A-Advanced Bicyclists</u> —
Experienced riders who can operate under

most traffic conditions. They comprise the majority of the current bicycle users of collector and arterial streets.

Group B-Basic Bicyclists—Casual or new adult and teenage riders who are less confident of their ability to operate in traffic without special provisions for bicyclists. The basic rider is comfortable riding on neighborhood streets and shared use paths but prefer designated facilities such as bike lanes or wide shoulder lanes on busier streets.

Group C-Children—Pre-teen riders whose roadway use is initially monitored by parents. Eventually they are accorded independent access to the system. Provisions should be made to allow access to key destinations without encouraging them to ride in the travel lane of major arterials.

In the design of bicycle facilities two broad classes of bicyclists are used: Group A riders and Group B/C riders.

Generally, the Group A bicyclist will be best served by designing all roadways to accommodate shared use by bicyclists and motor vehicles. This can be accomplished by:

- Providing wide outside lanes or bike lanes on collector and arterial streets built with an urban section (i.e., with curb and gutter);
- Providing useable shoulders on highways built with a rural section (i.e., no curb and gutter).

Group B/C bicyclists are best served by a network of neighborhood streets and designated bicycle facilities that can be provided by:

- A network of designated bicycle facilities (e.g., bike lanes, separate bike paths, or side-street bicycle routes) through the key travel corridors typically served by arterial and collector streets.
- Useable roadway shoulders on rural highways, 4 ft [1.2 m] wide.

## 10.9.1 FACILITY SELECTION

The most significant factors affecting compatibility of roadways for bicycling are motor vehicle traffic volumes, operating speed, and the width of the travel lane and shoulder. The selection of facility type should be determined by an analysis of these factors in addition to the following:

1. State and local bicycle master plans;
2. Proximity of schools, parks and other destinations where a child bicyclist may be expected;
3. Presence of a regionally significant or locally designated bicycle route;
4. Potential turning movement conflicts; and
5. Environmental, historical and right-of-way constraints.

In general, additional travel lane or shoulder width can increase the suitability of a roadway for bicycling. Designation of bicycle lanes with appropriate signs and pavement markings will help increase the predictability of both bicycle and motor vehicle movements. Additional separation of bicycle traffic from motor vehicle traffic on shared use paths may be desirable on high speed, high volume roadways, where an increase in child bicyclists can be expected or along regional pathway networks. Development of a shared use path does not preclude the need to accommodate more experienced bicyclist on the roadway.

## 10.9.2 FACILITY TYPES

Four basic types of facilities are used to accommodate bicyclists:

1.Shared Roadway—(No Bikeway Designation)

Shared lanes are streets and highways with no special provision for bicyclists.

Shared lanes typically feature 12 ft (3.6 m) lane widths or less with no shoulders, allowing cars to safely pass bicyclists only by crossing the centerline where permissible or moving into another traffic lane.

In residential areas with lane widths of at least 12 ft [3.6 m] low motor vehicle traffic volumes and average motor vehicle speeds of less than 30 mph [50 km/h], shared lanes will accommodate group A riders, and will normally be adequate for group B/C bicyclists. Where the existing lane width is less than 12 ft [3.6 m], additional lane width is called for. For higher speeds and traffic volumes, shared lanes become less attractive routes, especially to group B/C riders.

2. Shared Roadway—Signed

These roadways are designated by bike route signs and either provide continuity to other bicycle facilities or designate a preferred route through high demand corridors.

In designating a roadway as a shared roadway, the Department must assure there are advantages to using this route, the route is suitable, and it will be maintained in a manner consistent with the bicyclist's needs. The use of signing and striping will advise the motorist to expect bicyclists and be prepared to react safely.

3. Bike Lane

Bike lanes are established with appropriate pavement marking and signing along streets in corridors where there is a significant bicycle demand. In order to accomplish this, space must be provided or created for preferential use by bicycles. Adequate space, pavement markings, traffic control, pavement conditions, surface hazards etc. must all be addressed. This will give both the bicyclist and the motorist a level of predictability of how each will maneuver.

Roads marked with bike lanes indicate that the road is recommended for safe cycling. This designation should not be made unless the bike lane will be a continuous safe route for the length of the bike lane (e.g. through intersections and turn lanes). In area where bicycle and motor vehicle traffic cross paths, pavement markings and signs should indicate the location of the bicycle lane and warn of potential conflict areas.

4. Shared Use Path

Shared use paths are on exclusive right-of-way and with a minimum of cross flow by motor vehicles. Users are non-motorized and may include bicyclists, in-line skaters, roller skaters, wheelchair users, and pedestrians, including walkers, runners, people with baby strollers, people walking dogs, etc.

#### 10.9.2.1 DESIGN APPROACH

Depending upon the information provided on the project initiation form and/or as a result of the project-scoping meeting, the designer might have to evaluate one or all of the four types of facilities as a part of the context sensitive design approach. Bicycles are a part of the available transportation system. If properly addressed, increased bicycle use can contribute to the reduction in air pollution and motor vehicle use.

### 10.9.3 SHARED ROADWAY

Most bicycle travel occurs on streets and roadways that have no bikeway designation (shared roadway) because the existing street system is adequate to handle safe and efficient bicycle travel. In reviewing a project for shared use, the most important item to consider is whether or not adequate space can be provided to allow safe shared use by the motorist and bicyclist. The items to be considered include adding paved shoulders, increasing lane widths, eliminating on-street parking, improving pavement surface quality, and providing safe drainage grates, utility covers, traffic control boxes, etc. in the useable area.

Improving or adding paved shoulders may be the best alternative to serve both modes. Other benefits of having shoulders are improved mainline drainage, protection of mainline pavement structure, emergency use, etc. The most obvious project effects are increases in design effort, construction costs, and right-of-way needs.

Paved shoulders should be at least 4 ft [1.2 m] wide to accommodate the bicyclist. However, any shoulder widening will be an improvement to the overall use and safety of the project. For the bicyclist, the useable shoulder width does not include the gutter pan, unless the gutter pan is 4 ft [1.2 m] or greater in width. Where guardrail is used, the shoulder width should be increased to 5 ft [1.5 m]. Greater motor vehicle speeds and volumes combined with increased use by bicyclists require that more shoulder width be provided. Design controls found in other chapters of this manual will usually be applied in these situations and will be adequate to serve bicyclists.

The use of rumble strips or raised pavement markings adjacent to shoulders warning errant drivers or discouraging the use of shoulders by motorist can be a problem for bicyclist. Rumble strips should be marked with a warning sign. Where they are to be used there should be:

(1) A clear path of 1 ft [0.3 m] from the rumble strip to the outside edge of the traveled way;

(2) A clear area of 4 ft [1.2 m] from the rumble strip to the outside edge of paved shoulder; or

(3) A clear area of 5 ft [1.5 m] to the adjacent guardrail, curb or other obstacle.

Where shoulders can not be provided, wider lane widths may be attainable. On roadway sections without designated bikeways, an outside lane, whether curbed or not, wider than 12 ft [3.6 m] can better accommodate the motorist, bicyclist and adjacent land use.

A useable lane width of 14 ft [4.2 m] is preferred when curb lanes are to be shared. This width does not include the gutter pan and is measured from the edge stripe to lane stripe or from the gutter pan edge to the lane stripe. Where there is a continuous steep grade, drainage grate interference, pavement reflectors, or on street parking, a curb lane width of 15 ft [4.5 m] is preferred. Too much width can be hazardous by encouraging the operation of two vehicles in a lane intended as a single lane operation.

Wide curb lanes have three widely accepted advantages. They can:

- Accommodate shared bicycle/motor vehicle use without reducing the roadway capacity for motor vehicle traffic;

- Minimize the real and perceived operating conflicts between bicycles and motor vehicles; and

- Increase the roadway capacity by the number of bicyclists capable of being accommodated.

Wide outside lanes require the least amount of additional maintenance of the different facilities. The sweeping effect of passing motor vehicles and routine highway maintenance is usually enough to keep the lane free of debris and in good condition for bicycling.

Wide outside lanes are especially valuable for Group A riders who are competent in sharing the roadway with motor vehicles. The same is not true for Group B/C riders. Except on residential or low-volume streets, wide outside lanes are not generally sufficient to provide the degree of comfort and safety required by less skilled bicyclists or children and will do little to encourage them to ride.

Wide curb lanes will be most applicable in urban areas on major streets where Group A riders will likely be operating. If no alternative exists for Group B/C riders, a bike lane or shoulder should typically be used.

The designer should not overlook the potential for encouraging bicycle use on rural routes. Adding 4 ft [1.2 m] of paved shoulder and a 4 in [100 mm] edge stripe can safely provide this.

Facilities with on-street parking provide greater opportunity for conflicts between cyclist and motorist since the rider will be between moving traffic and parked vehicles. The bicyclist is subject to opening car doors, exiting vehicles, extended mirrors that narrow travel space and reduced visibility. Where this type of operation is to be permitted, a parking lane of a minimum width of 12 ft [3.6 m] is needed.

The shared roadway can also be occupied by existing or proposed surface obstacles to the bicyclist. These include drainage grates, utility covers and traffic control appurtenances. Throughout the design and construction phases these obstacles should be ether eliminated or designed to accommodate bicycle use.

## 10.9.4 SIGNED SHARED ROADWAY

Signed shared roadways are those that have been identified as bicycle routes and are signed accordingly. The reasons for designating a certain route as preferred for bicycle use include:

- The route provides continuity to other bicycle facilities,
- The road is a common route through a high demand corridor,
- In rural areas, the route is preferred due to low motor vehicle volumes, aesthetics, or availability of paved shoulders, or
- The route extends along local streets and collectors leading to a neighborhood destination such as a park, school or commercial district.

Signing a particular route suggests that there are advantages to using this route rather than some other alternative. This designation implies that certain criteria have been established and are being maintained. Criteria to be considered prior to selecting a route for designation include:

- In high demand corridors, the route is a direct through route;
- The route connects discontinuous segments of other types of bicycle facilities;
- Traffic control devices have been adjusted to reflect increased bicycle use;
- Street parking has been removed or restricted where width is critical to provide safe travel;
- A smooth surface has been provided;
- Maintenance will be provided to remove accumulated debris and keep traffic control devices serviceable;
- Wider curb lanes are provided as compared to parallel alternative routes; and
- Shoulder or wider lane widths meet the established minimums.

## 10.9.5 BIKE LANES

A bike lane is a portion of the roadway that has been designated by striping, signing and pavement markings for the preferential or exclusive use of bicyclists. Four typical bike lane layouts are shown in Figure 10-6.

Bike lanes are considered when it is desirable to delineate available road space for preferential use by bicyclists. The beginning and end of the bike lane should be clearly signed and marked. Bike lanes should not be designated on roads where the lane must bend in an unsafe location.

Bike lane markings can increase a bicyclist's (especially B/C riders) confidence in motorists not straying into his/her path of travel. Likewise, passing motorists are less likely to swerve to the left out of their lane to avoid bicyclists on their right. Provision with appropriate signage should be made for a continuous bike lane through turn lanes and at intersections. On high-speed roadways where a left turn lane is introduced, a bike lane should be continued on the right of the high-speed lane.

Bike lanes should be one-way facilities and carry traffic in the same direction as adjacent motor vehicle traffic. Two-way bike lanes on one side of the roadway are not recommended when they promote riding against the flow of motor vehicle traffic. Wrong-way riding is a major cause of bicycle accidents and violates the Rules of the Road as stated in Delaware's Uniform Vehicle Code. Bike lanes on one-way streets should be on the right side of the street, except in areas where a bike lane on the left will decrease the number of potential conflicts (e.g., conflicts with heavy bus traffic). Contra flow bike lanes may be considered in exceptional circumstances in urban area where appropriate traffic control devices may be used to ensure the safety of users.

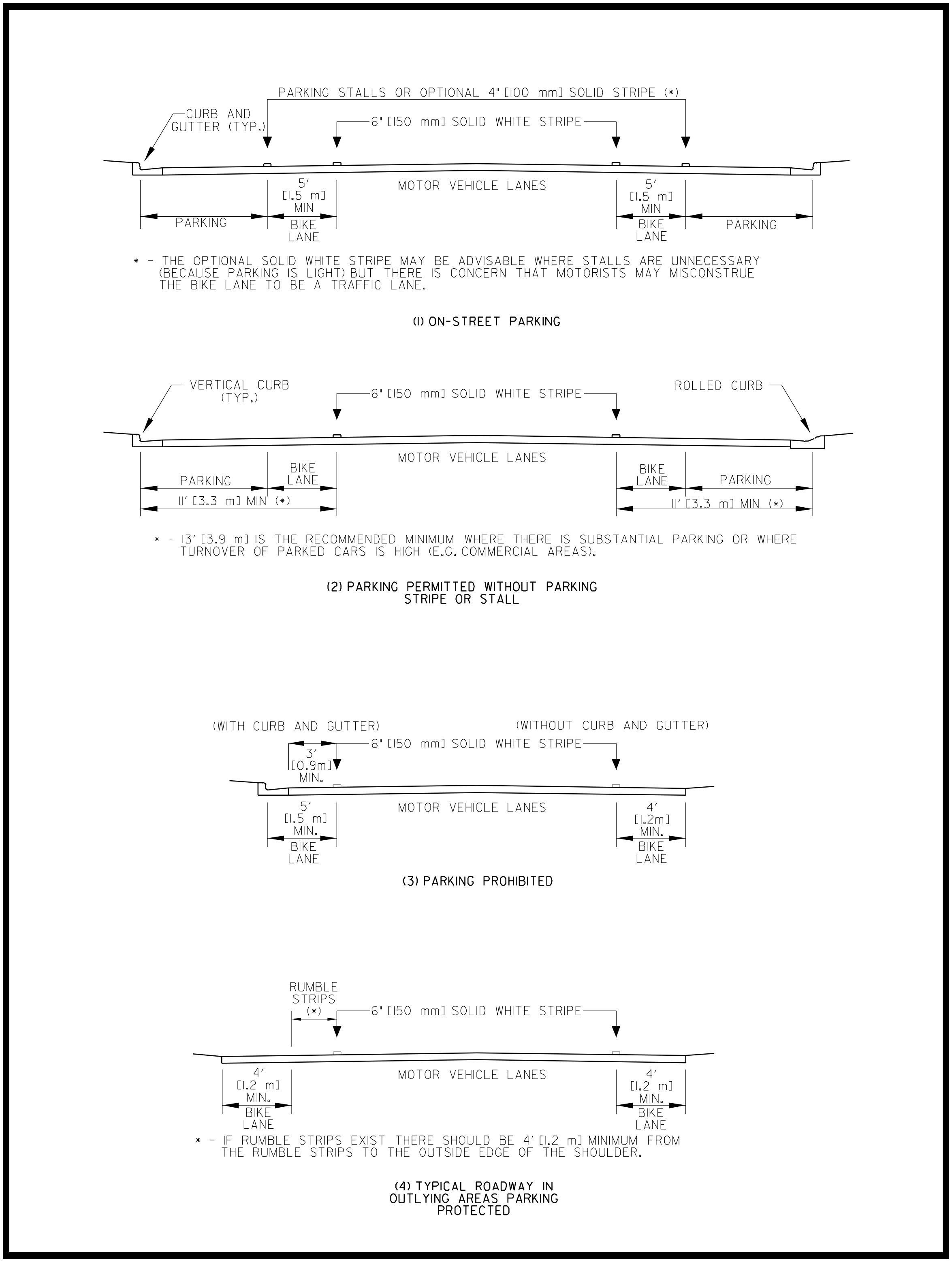
For roadways with no curb and gutter, the minimum bike lane width is 4 ft [1.2 m]. Certain edge conditions indicate the need for additional bike lane width. If parking is permitted, the bike lane should be placed between the parking area and the travel lane and have a minimum width of 5 ft [1.5 m].

Where parking is permitted but a parking stripe or stalls are not utilized, the shared area should be a minimum of 11 ft [3.3 m] without a curb face and 12 ft [3.6 m] adjacent to a curb face. If the parking volume is substantial or turnover is high, an additional 1 to 2 ft [0.3 to 0.6 m] is desirable. Bike lanes between the curb and the parking lane can create obstacles for bicyclists from opening car doors and poor visibility at intersections and driveways, and they also prohibit bicyclists from making left turns. Therefore this placement should not be considered. Bike lanes are not advisable where angled parking exists.

Bike lanes along the outer portions of an urban curbed street, where parking is prohibited, also require special consideration. Bicyclists do not generally ride near a curb because of the possibility of debris, hitting a pedal on the curb, an uneven longitudinal joint, or a steeper cross slope. Bike lanes in this location should have a minimum width of 5 ft [1.5 m] from the curb face. If the longitudinal joint between the gutter pan and the roadway surface is uneven and falls within 5 ft [1.5 m] of the curb face, a minimum of 4 ft [1.2 m] should be provided between the joint and the motor vehicle lanes.

Bike lanes should be placed within the paved shoulder area at the outside edge in rural areas having a roadway section without curb, gutters and with infrequent parking. Bike lanes should have a minimum width of 4 ft [1.2 m]. Where the shoulder can provide additional maneuvering width, a width of 5 ft [1.5 m] or greater is preferable; additional widths are desirable where substantial truck traffic is present, or where there are excessive vehicle speeds.

## *Figure 10-6*
## *Typical Bike Lane Cross Sections*



A bike lane should be delineated from the motor vehicle travel lanes with a 6 in [150 mm] wide solid white line. Bike lanes should be provided with adequate drainage to prevent water ponding, washouts, debris accumulation and other potential hazards to the bicyclist. Adequate pavement surface, bicycle-safe grate inlets, safe railroad crossing, and traffic signals responsive to bicycles should always be provided on roadways where bicycle lanes are being designated. Raised pavement markings and raised barriers can cause steering difficulties for bicyclists and should not be used to delineate bicycle lanes.

#### 10.9.5.1 INTERSECTIONS WITH BIKE LANES

Bike lanes tend to complicate both bicycle and motor vehicle turning movement at intersections. Because they encourage bicyclists to keep to the right and motorists to keep to the left, both operators are somewhat discouraged from merging in advance of turns. Thus, some bicyclists will begin left turns from the right side bicycle lane and some motorists will begin right turns from the left of the bicycle lane. Both maneuvers are contrary to established rules of the road and result in conflicts.

At intersections, bicyclists proceeding straight through and motorists turning right must cross paths. Striping and signing configurations that encourage these crossings in advance of the intersection, in a merging fashion, are preferable to those that force the crossing in the immediate vicinity of the intersection.

The design of a bike lane needs to include appropriate pavement markings and signing approaching and through intersections to reduce the number of conflicts. Guidance for signing and pavement marking of bike lanes is shown in the MUTCD and AASHTO's G*uide for the Development of Bicycle Facilities.*

### 10.9.6 SHARED USE PATH

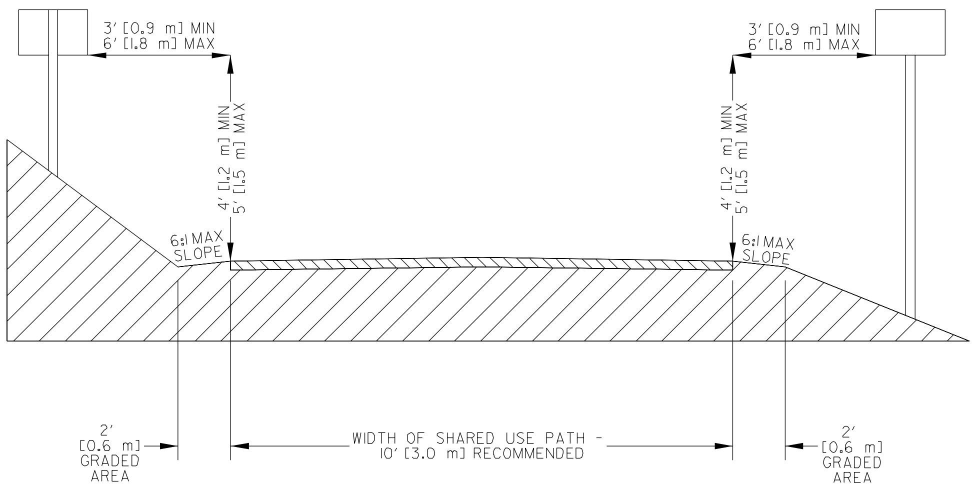
A shared use path is a facility that is physically separated from the roadway and intended for exclusive use of modes other than motorized vehicles. Initially perceived as bicycle paths, these facilities have grown in popularity serving bicyclists, in-line skaters, roller skaters, wheelchair users, and pedestrians, including, walkers, runners, people with baby strollers, people walking dogs, etc.

These facilities should be designed in accordance with the Americans with Disabilities Act standards for shared transportation paths. Maximum slope, cross slope and the rate of change in grade should be carefully examined during the design process. Because of their multi-use attraction they are a valuable addition to the highway system and to the range of facilities available to planners and engineers seeking to improve conditions for all categories of travelers. They can serve both a transportation and recreational function and have proven to be significant generators of bicycle use. Groups A and B/C riders (as well as other non-motorized users) can benefit from the absence of motor vehicle traffic on these paths. If bicycle and pedestrian volumes are expected and large numbers of conflicts are expected, a separate pedestrian facility may need to be considered.

The inclusion of a shared use path in a project would be the result of the planning process and be fully described in the project initiation documentation. Figure 10-7 shows the layout for a typical shared use path.

Shared use paths provide users with a shortcut through residential areas, provide enjoyable recreational opportunity, and

*Figure 10-7*
*Cross Section of Two Way Shared Use Path on Separate Right of Way*




provide access to areas not accessible by motor vehicle and areas only accessible by limited access highway facilities closed to this type of user.

Separate bike paths may be referred to as "multi-use trails" or "greenways" even though they are slightly different facilities. A trail typically runs along an independent right of way such as an abandoned railroad corridor, and a greenway is a park-type corridor of land that may or may not incorporate a trail within its boundaries.

The design criteria categories that apply to shared-use paths are based on those used for highways including horizontal alignment, vertical alignment, vertical and lateral clearances, sight distance, grades and pavement structures. The similarity does not carry over into the actual criteria as the operational characteristics are significantly different.

Even when providing a shared path, street improvements to address this mode of transportation should not be overlooked. Many users will still use the local street system perceiving it to be more convenient, safer and better maintained, particularly for utility trips.

### 10.9.6.1 SEPARATION BETWEEN SHARED USE PATHS AND ROADWAYS

One of the most important elements in designing a successful shared path is the separation between the path and any adjacent roadways. Unless there is adequate separation there will be operational problems that make it more desirable and convenient for the user to use the roadway.

The minimum separation of a bicycle path from a roadway is 5 ft [1.5 m]. When this minimum is not possible a suitable barrier at least 44 in [1.1 m] in height should be provided.

Problems associated with locating shared use paths too close to a roadway include:

- Requires one direction of bicycle traffic to ride against motor vehicle traffic;
- Upon entering or leaving a path bicyclist going against traffic tend to continue on the wrong side;
- Creates nonstandard flow conflicts at intersections;
- Signs posted for roadway users are backwards for the contra flow bicyclist;
- Many bicyclists will perceive the roadway as more convenient, better maintained or safer;
- At intersections and entrances, drivers expect the bicyclist to stop or yield but this does not usually happen;
- Stopped vehicles at cross-streets and vehicles exiting side streets and driveways block the path; and
- The distance between the two facilities may require the use of a barrier creating a hazard to the bicyclist and the motorist.

Because of the problems when shared use paths are located too close to a roadway, other types of bikeways may be more practical for accommodating bicyclists.

**10.9.6.2 WIDTH AND CLEARANCE**

Two-way shared paths should be a minimum of 10 ft [3.0 m] wide. In high use areas it may be desirable to increase the width to 12 ft [3.6 m].

A minimum graded area of 2 ft [0.6 m] in width should be maintained adjacent to both sides of the pavement. However 3 ft [0.9 m] or more is desirable to provide clearance from trees, poles, walls, fences, guardrails, or other lateral obstructions. A minimum 5 ft [1.5 m] separation from the edge of the path pavement to the top of slope is desirable. Depending upon the height of embankment, it may be necessary to provide a physical barrier.

The minimum width of a one-directional shared use path is 6 ft [1.8 m]. However, without adequate enforcement, it can be anticipated that the path will be used as a two-way facility and designed accordingly.

The vertical clearance to obstructions should be a minimum of 8 ft [2.4 m], however, vertical clearance may need to be greater to permit passage of maintenance vehicles and, under crossings and tunnels, a clearance of 10 ft [3 m] is desirable for adequate vertical shy distance.

**10.9.6.3 DESIGN SPEED**

The bicyclist controls the design speed and is dependent on several factors, including the type and condition of the bicycle, the purpose of the trip, the condition and location of the shared use path, the speed and direction of the wind and the physical condition of the bicyclist. Shared use paths should be designed for a selected bicycle speed that is at least as high as the preferred speed of the faster bicyclist. In general, a minimum design speed of 20 mph [30 km/h] should be used; however, when the grade exceeds 4 percent a design speed of 30 mph [50 km/h] is advisable.

For most bicycle path applications the superelevation rate will vary from a minimum of 2 percent (the minimum necessary to encourage adequate drainage) to a maximum of approximately 3 percent (beyond which maneuvering difficulties by slow bicyclists and adult tricyclists might be expected). The minimum superelevation rate of 2 percent will be adequate for most conditions and will simplify construction.

For a superelevation rate (e) of 2 percent, the minimum radii of curvature is 80 ft [25 m] for a design speed of 20 mph [30 km/h] and 260 ft [80 m] for a design speed of 30 mph [50 km/h]. When substandard radius curves must be used on bicycle paths due to right-of-way restrictions, topographical or other considerations, standard curve warning signs and supplemental pavement markings should be installed in accordance with the MUTCD. The negative effects of substandard curves can also be partially offset by widening the pavement through the curves.

**10.9.6.4 GRADES**

Grades on shared paths should be kept to a minimum, especially on long inclines. Grades greater than 5 percent are undesirable because the ascents are difficult for many bicyclists to climb and the descents cause some bicyclists to exceed the speeds at which they are competent. Where terrain dictates, grades over 5 percent and less than 500 ft [150 m] long are acceptable when a higher design speed is used and additional width is provided. Grades steeper than 3 percent may not be practical for shared paths with crushed stone or other unpaved surfaces because of handling and increased maintenance problems.

If excessive grades must be used there are several alternatives to address this problem. These are:

- Widen the path to allow slower users to walk;
- Provide signing, alerting users of the steep slope ahead;
- Provide recommended speed signs,
- Exceed the minimum stopping sight distance;
- Exceed the minimum horizontal clearances, recovery areas, and if necessary add protective rails; or
- Design the path with a series of switchbacks.

**10.9.6.5 HORIZONTAL ALIGNMENT**

Unlike a motor vehicle, a bicycle must be leaned when entering a curve to prevent it from falling outward. If the bicyclist pedals through a curve and leans too far, the pedal may strike the surface. Depending upon the ability of the bicyclist, the lean angle may vary. Pedal heights may differ, but generally a 25$^{o}$ lean angle will cause the pedal to strike the surface. In design, a lean angle of 15-20$^{o}$ should be used.

The following equations are used to determine the minimum radius of curvature.

For US Customary Units:

$$R = \frac{0.067V^2}{\tan\theta}$$

For Metric Units:

$$R = \frac{0.0079V^{2}{}'}{\tan\theta}$$

Where:

R = Minimum radius of curvature ft [m]
V = Design Speed mph [km/h]
θ = Lean angle from the vertical (degrees)

When the lean angle approaches $20^0$, the minimum radius becomes a function of the superelevation of the pathway surface, the coefficient of friction between the bicycle tires and surface and the speed of the bicycle. For this design condition, the minimum radius or curvature can be derived from the equation:

For US Customary Units:

$$R = \frac{V^2}{15\left(\frac{e}{100} + f\right)}$$

For Metric Units:

$$R = \frac{V^2}{127\left(\frac{e}{100} + f\right)}$$

Where:

R = Minimum radius of curvature ft [m]
V = Design speed mph [km/h]
*e* = Rate of bikeway superelevation (percent)
*f* = Coefficient of friction

The equation variables are limited in range. Shared paths are subject to the Americans with Disabilities Act. Cross slopes are limited to a maximum of 3 percent. Friction factors are controlled by the rider's sense of discomfort. Figures 10-8 and 10-9 provide an easy reference for design application.

If the minimum radius is not attainable, warning signs and other supplemental signing as per the MUTCD should be installed

### 10.9.6.6 SIGHT DISTANCE

The sight distance accommodating bicycle traffic usually controls the design of a shared use path. In some cases, sight distance for pedestrians and wheelchair users should be considered as well.

**Figure 10-8**
**Desirable Minimum Radii for Paved Shared Use Paths[1]**

| Design Speed (V) mph [km/h] | Minimum Radius (R) ft [m] |
|---|---|
| 12 [20] | 36 [12] |
| 20 [30] | 100 [27] |
| 25 [40] | 156 [47] |
| 30 [50] | 225 [74] |

[1]Based on a $15^0$ lean angle

**Figure 10-9**
**Minimum Radii for Paved Shared Use Paths[1]**

| Design Speed (V) mph (km/h) | Friction Factor (*f*) (paved surface) | Minimum Radius (R) ft (m) |
|---|---|---|
| 12 [20] | 0.31 | 30[10] |
| 20 [30] | 0.28 | 90 [24] |
| 25 [40] | 0.25 | 1155 [47]] |
| 30 [50] | 0.21 | 260 [86] |

[1]Paths Based on 2% Superelevation Rate and $20^0$ Lean Angle

To provide bicyclists with an opportunity to see and react to the unexpected, a shared use path should be designed with adequate stopping sight distance. The distance required to bring a bicycle to a full controlled stop is a function of the bicyclist's perception and brake reaction time, the initial speed of the bicycle, the coefficient of friction between the tires and the pavement, and the braking ability of the bicycle.

The minimum stopping sight distance of bicycles is based on a total perception and brake reaction time of 2.5 seconds and a coefficient of friction of 0.25, to account for the poor wet weather braking characteristics of many bicycles. For two-way bicycle paths, the sight distance in descending direction, that is, where G is negative, will control the design. Sight distance is calculated using the following equation(s):

For US Customary Units:

$$S = \frac{V^2}{30(f \pm G)} + 3.67V$$

For Metric Units:

$$S = \frac{V^2}{254(f \pm G)} + \frac{V}{1.4}$$

Where:

S = Minimum stopping sight distance, m
V = Design Speed, mph [km/h]
G = Grade, ft/ft [m/m] (descending - Neg., Ascending +Pos.)

The minimum length of vertical curve necessary to provide minimum stopping sight distance at various speeds on crest vertical curves is given by the following equation. The assumptions used for the equation are the eye height of the bicyclist is 4.5 ft [1.4 m] and a object height of zero recognizing that impediments to bicycle travel exist at pavement level.

For US Customary Units:

When S>L  L = 2S-900/A
When S<L  L = $AS^2$/900

For Metric Units:

When S>L  L = 2S-(280/A)
When S<L  L = $AS^2$ /280

Where:

L = Minimum Length of Vertical Curve ft (m) ≥ 3 ft [1.0 m]
S = Stopping Sight Distance ft [m]
A = Algebraic difference (%)

Height of bicyclist eye = 4.5 ft [1.4 m]

Height of object = 0 ft [0 m]

Bicyclists frequently ride abreast on bicycle paths. On narrow bicycle paths, bicyclists have a tendency to ride near the middle of the path. For these reasons, and because of the serious consequences of a head on bicycle accident, lateral clearances on horizontal curves should be calculated based on the sum of the stopping sight distances for bicyclists traveling in opposite directions around the curve. Where this is not possible or feasible, consideration should be given to widening the path through the curve, installing a yellow center stripe, installing a curve ahead warning sign in accordance with the MUTCD, or some combination of these alternatives.

Tables and curves for solutions of both sight distance equations, under various design conditions, can be found in AASHTO's *Guide for the Development of Bicycle Facilities.*

### 10.9.6.7 INTERSECTIONS

Intersections with roadways are important safety considerations in shared path design. There are three basic types of path-roadway intersections: mid-block, adjacent path and complex. If alternate locations are available, the one with the most favorable intersection conditions should be selected.

Mid-block crossings should be located far enough from the intersection to remain outside of the vehicular traffic mix approaching and entering an intersection. It may be preferable to provide a mid-block bicycle path crossing at a minimum distance of 100 ft [30 m] from the vehicular intersection. There are other elements that need to be considered in this type of crossing, including right of way assignment, appropriate traffic control devices, sight distance, refuge islands and pavement markings. The preferred intersecting angle for this type of crossing is $90^0$.

Adjacent path intersections occur when the path is parallel to a roadway and it crosses a driveway or other intersecting roadway such as a T-intersection or a simple four-legged intersection. In designing this type of crossing it is important to keep the location close to the intersection. This allows the motorist and path user to recognize they are a part of the traffic mix and to be prepared to react accordingly. In this situation, the user is faced with multiple conflicts.

The major roadway may be the parallel route or the intersecting roadway. It is necessary to clearly definite rights of way and the appropriate traffic control devices adjusted to reflect the addition of the shared path component in the intersection flow. Considerable traffic engineering must be utilized to make this type of crossing safe.

Complex intersections are defined as all other types of intersections of paths with roadways. These intersections are unique and must be designed as site specific. Several alternative treatments are available such as moving the crossing, installing a signal, changing signalization timing, or providing a refuge island.

If these or other safe solutions are not possible, it may be preferable to have the cyclist dismount and walk the bicycle across the intersection. Designers should insure that adequate signing is in place to alert both vehicles and bicycle users of their design intent.

In most cases, the cost of grade separating the shared use path from the highway will be cost prohibitive. However, for crossings of freeways and other high speed, high volume arterials, a grade separation structure may be the only possible or practical treatment.

When intersections occur at grade, a major consideration is the establishment of right-of-way. The type of traffic control to be used (signal, stop sign, yield sign, etc.), and location, should be provided in accordance with the MUTCD.

Sign type, size and location should also be in accordance with the MUTCD. Care should be taken to ensure that shared use path signs are located so that motorists are not confused by them and that roadway signs are placed so that shared use path users are not confused by them.

It is preferable that the crossing of a shared path and a roadway be at a location away from the influence of intersections with other highways. Controlling vehicle movements at such intersections is more easily and safely accomplished through the application of standard traffic control devices and normal rules of the road. Where physical constraints prohibit such independent intersections, the crossings may be at or adjacent to the pedestrian crossing. Who yields the right of way should be assigned and sight distance provided so as to minimize the potential for conflict resulting from unconventional turning movements. At crossings of high-volume, multi-lane arterial highways where signals are not warranted, consideration should be given to providing a median refuge area for the shared path user. Where shared use paths intersect at highway intersections it may be preferable for the bicyclist to dismount and walk the bicycle through the intersection using pedestrian crosswalks. Adequate signing must be provided to alert the bicyclist of this condition.

When shared use paths terminate at existing roads, it is important to integrate the path into the existing system of roadways. Care should be taken to properly design the terminals to transition the traffic into a safe merging or diverging situation. Appropriate signing is necessary to warn and direct both bicyclists and motorists regarding these transition areas.

Bicycle path intersections and approaches should be on relatively flat grades. Stopping sight distances at intersections should be checked and adequate warning should be given to permit bicyclists to stop before reaching the intersection, especially on downgrades.

Curb ramps at intersections should be the same width as the shared use path. Curb ramps should provide a smooth transition between the shared use path and the roadway.

#### 10.9.6.8 RESTRICTION OF MOTOR VEHICLE TRAFFIC

Shared use paths need some form of physical barrier at highway intersections to prevent unauthorized motor vehicles from using the facilities. Provisions can be made for a lockable, removable post to permit entrance by authorized vehicles. The post should be permanently reflectorized for nighttime visibility and painted a bright color for improved daytime visibility. When more than one post is used, 5 ft [1.5 m] spacing is desirable. Wider spacing can allow entry to motor vehicles, while narrower spacing might prevent entry by adult tricycles and bicycles with trailers.

An alternative method of restricting entry of motor vehicles is to split the entryway into two 5 ft [1.5 m] sections separated by low landscaping. Emergency vehicles can still enter if necessary by straddling the landscaping. The higher maintenance costs associated with landscaping should be considered.

#### 10.9.6.9 OTHER DESIGN ISSUES

The preferred pavement surface is a good quality all weather surface. Designing the pavement structure is similar to that of a roadway. Design is based on soil investigation to determine the load carrying capacity of the existing soils. In this case, the controlling load is that of motorized maintenance and patrol vehicles. The pavement selection is influenced by frost damage potential, skid resistance, surface quality, edge support, and surface and subsurface drainage.

Motor vehicle grade separations pose a design problem for the shared use path. The first consideration is whether or not safe continuity can be provided, particularly on existing structures. A clear width equal to the approach width of the shared use path plus a lateral offset of 2 ft [0.6 m] is desirable. Vertical clearances are controlled by the motor vehicle traffic. Railing, fences or barriers on both sides of the path across the structures should be a minimum of 44 in [1.1 m] high. Expansion joints should be "bicycle friendly".

Drainage design for shared paths is similar to that of a roadway. A cross slope of 2 percent in one direction with no crown is preferred and also simplifies the construction. Side ditches, ground cover, erosion and all other drainage design elements are a part of the path design.

Designating a sidewalk as a shared use path is not recommended, even if the sidewalk is wider than normal. The introduction of a diversity of users (bicyclists, rollerbladers, etc.) and their particular operational characteristics will cause safety problems for all users. Sidewalks as a shared use path should be limited to a high speed or heavily traveled area or across long narrow structures where continuity of the path is desirable.

## 10.10 BUS STOPS

The Delaware Transit Corporation (DTC) establishes policy and design guidelines for bus stops and other transit related facilities. As part of the project development process highways and corridors served by transit will be identified and appropriate facilities included in the project. The following is a general discussion on bus stops. For specifics, the designer should refer to the Delaware Transit Corporation's Policy: *Bus Stop and Passenger Facilities Standards."*

**10.10.1 LOCATION CRITERIA**

Bus stops are generally located at or near major trip generators, destinations or at regular intervals based on the population density and other related demographic transit related criteria. Stops are located where passengers can board and alight safely and where buses can safely enter and exit the traffic flow. Sidewalks and walkways serving bus stops should separate pedestrians from vehicular traffic. Whenever, possible, stops in opposite directions on a route should be located directly opposite each other.

Bus stops should not obstruct driveways or entranceways nor cause visual obstruction for motorists or the bus driver merging back into traffic. In areas that have high traffic volumes, significant turning movements and pedestrian crossings, the stop should be placed where it will present the least conflict.

**10.10.2 BUS STOP DESIGN**

The three basic configurations for bus stops are (see Figure10-10):

- Far-side (placed immediately after an intersection),
- Near-side (placed immediately before an intersection), and
- Mid-block (placed between intersections or along the side of a stretch of roadway).

All three of these configurations have advantages and disadvantages. Of the three, far-side curb stops, those placed at the far side of the intersection, are preferred in high traffic areas because they allow for better bus operation and traffic and pedestrian flow. After determining the stop configuration, the bus stop zone design type must be selected. Figures 10-11 through 10-17 show the layout and design parameters for the five types of stop zones. These are:

- Curbside—those placed in parking or running lanes adjacent to the curb.
- Bus Bay—a separate lane outside the influence of an intersection, with appropriately designed deceleration and acceleration lanes.
- Open Bus Bay—a separate lane on the far side of an intersection with an acceleration lane. The intersection area is used as the deceleration lane.
- Queue Jumper Bus Bay—a separate lane on the far side of an intersection where the right turn lane is used by the bus to by-pass the signal queue. An appropriate acceleration lane is provided.
- Nub—In a location with on-street parking, the curb is extended toward the travel lane, removing available parking, creating an area large enough to permit the bus to stop at curb side, in the running lane.

Bus bay, open bus bay and queue jumper bus bay designs provide a protected area away from moving traffic and minimize delay to through traffic. However, they present problems for the bus to reenter the traffic flow, are expensive to install, result in the removal of considerable parking spaces and, perhaps the greatest disadvantage, are difficult and expensive to move. The nub type has similar advantages to the curbside type. However, in most situations the disadvantages due to the operational area required, cost to install and loss of parking outweigh the advantages.

The preferred type of stop is the curb-side stop which provides easy access for the bus, results in minimal delay, is simple to design, easy and inexpensive to install and easy to relocate. The disadvantages are, when placed in the running lane, that they cause traffic to back up and may lead drivers to unsafe maneuvers to avoid the stopped bus. With advanced signing and driver expectation these disadvantages are minimized. In areas with permitted on-street parking, removal of parking spaces within the stop zone is required but not to the limits required by the other types of bus stop zones.

Curbside bus stop zones are the portions of the roadway marked and signed for use by buses. Bus stop zones should be a minimum of 90 ft [27 m] for far-side stops, 100 ft [30 m] for near side stops, and a minimum of 150 ft [45 m] for mid-block stops. Bus stop zones lengths may have to be extended depending on the rate of bus arrivals and passenger service time at the stop. Bus bays, also known as turnouts, are specially constructed areas separated from the travel lanes and off the normal roadway section. The design allows through traffic to flow freely when encountering a stopped bus. Bus bays are usually constructed on high-volume or high-speed roadways or heavily congested downtown shopping areas with large rider usage. On high volume roadways bus bays must be designed properly or they may be avoided by the bus driver due to the extreme difficulty maneuvering and lost time required in returning to the traffic flow.

Bus bay design is based on criteria that considers the established roadway speed, the entering bus speed, the required deceleration acceleration and tapers to allow for entrance and exit of the bus, plus the required stopping area allowed for boarding and alighting. The higher the traffic speeds the greater all these dimensions plus the lane width become. In urban areas far-side intersection placement of bus bays is preferred.

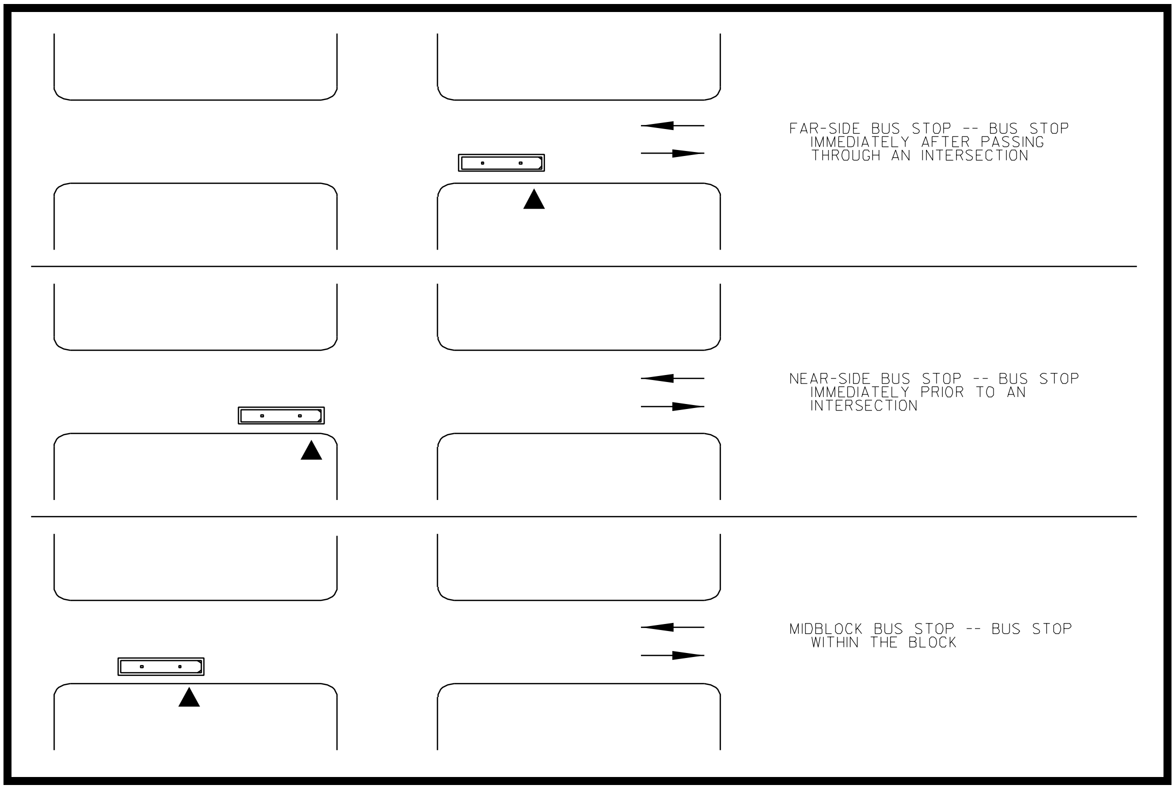
The open bus bay design is a variation of the bus bay design with the entrance end open to the upstream intersection. The bus driver has the pavement width of the upstream cross street available to decelerate and to move into the bay. The advantages of this design are that it allows efficient bus movement and permits free flow of traffic. The disadvantage is to the crossing pedestrians who have a greater distance to cross the intersection and encounter another potential conflict, particularly if the impatient vehicle driver decides to use this lane to avoid the queue. To minimize the disadvantages, a partial-open bus bay design may be considered. This alternative maintains the roadway curb line at the far side of the intersection creating a bubble that allows the buses to use the intersection approach in entering the bay and provides a partial sidewalk extension to reduce pedestrian crossing distance.

Queue jumper bus bays provide priority treatment for buses along arterial streets by allowing buses to bypass the queue at intersections. These bus stops consist of a near-side and far-side open bus bay. Buses are allowed to use the right turn lane to bypass congestion and proceed through the intersection. The right turn lane is appropriately signed to allow for this maneuver. The benefits of queue jumper stops are that they remove the bus from congested intersections and installation costs are affordable. When right turn lane volumes becomes too high an exclusive bus lane may be needed.

Nubs are sections of sidewalk that taper from the curbed parking lane to the edge of the travel lane creating an area prior to and around the intersection radius. The bus operates similar to curbside stops. Nubs are used on low speed and/or low volume streets where right turn lanes are not warranted. They are considered at locations of high pedestrian activity, crowded sidewalks, where pedestrian crossing distances need to be decreased, and where stopped buses in the travel lane can be tolerated. Nubs can be used both as bus stops and traffic calming measures.

Once a bus stop configuration is selected a design vehicle representative of those in the fleet must be determined. The most commonly used bus is the standard 40 ft [12 m] bus. Articulated 60 ft [18 m] buses may be a part of the fleet. Normally the dimensions typical for a standard 40 ft [12 m] bus are used for design. The design features that are affected by the design vehicle decision are lane and shoulder widths, lateral and vertical clearances, vehicle storage lengths, minimum turning radii, and the pavement strength.

***Figure 10-10***
***Bus Stop Placement***




Safe pedestrian access to the bus stop is important. Placing stops where there is an existing sidewalk network meeting all the criteria of the Americans with Disabilities Act to accommodate the disabled and physically challenged is the desired location. The accessible path to the stop should be well drained and, where possible, placed in street lighted areas.

The pathway to the bus stop should have the following characteristics:

- Clear width of at least 3 ft [0.9 m], preferably 5 ft [1.5 m] (the minimum width needed to allow passage of two wheelchairs)
- Running slope of pathway can be no greater than 8%
- The surface of the pathway must be firm and well-drained
- The path must comply with accessibility guidelines for curb cut at all street intersections.

Whether or not to install bus shelters is a Decision of the Delaware Transit

Corporation (DTC). Primarily the number of passenger boardings per day guides this decision. However, consideration is also given to the number of transfers at a stop, the volume and frequency of transit service, the number of disabled and elderly users, the proximity to major activity areas and available space. More detail is available in DTC policy *Bus Stops and Passenger Facilities Standards.*

## ″10.11 PARK-AND-RIDE LOTS

DTC is responsible for establishing and maintaining park-and-ride lots. DTC is involved in the project development process to ensure site feasibility and conformance with intended use. This section is a general discussion on park-and ride facilities. The designer should refer to Delaware Transit Corporation's Policy: *Bus Stops and Passenger Facilities Standards*.

Park-and-ride lots are intended to provide a common location for individuals to transfer from low- to high-occupancy travel modes. The overall objective is to maximize the efficiency of the transportation system and to provide commuter options. In addition to serving locations to transfer automobile users to a transit facility, they are created at selected locations to encourage the formation of carpools and vanpools.

In providing this travel alternative, there are five types of park-and ride facilities; (1) remote, (2) local service, (3) peripheral, (4) exclusive use, and (5) shared-use. Remote park-and-ride lots are located relatively far from a major activity center and/or the final destination of users. Remote lots serve residents of rural and suburban areas and community centers allowing them to travel to and from central business districts or other high employment centers in a mode other than a single occupancy vehicle (SOV). To be successful they need to intercept automobiles close to the residential area or home. In order to do this, they are usually located relatively close to heavily traveled corridors.

Local service park-and-ride lots are located at the end of a local transit route. These lots are located closer to desired destinations and serve residential neighborhoods at the end of the routes, as well as those along the route. Peripheral park-and-ride lots are located on the edge of a major activity center. These lots function to expand the available parking and to intercept automobiles before entering the congested area. These types of facilities do not eliminate the commute trip. The last part of the trip into the most congested areas is made by transit. Ideally carpools and vanpools form at peripheral lots to use this facility for transfer to transit serving individual destinations.

Exclusive use park-and-ride lots are planned, designed, constructed and operated specifically to serve as park-and-ride lots. Remote park-and-ride lots are usually exclusive facilities. However, these types of facilities are more generally associated with rail systems, high occupancy vehicle lanes, or express bus services. These lots have a high use rate, provide passenger amenities, and have frequent peak-hour service. Because they are designed exclusively to serve as a park-and-ride, provisions for adequate parking, efficient bus operation, pedestrian circulation and safety are a necessity. In order to accomplish this, these facilities have a high cost.

Shared-use lots serve several functions with only a portion designated as a park-and ride area. They may be located in a shopping center, church, school, or other activity center parking lot. Shared-use lots are usually located along an existing bus route. The advantage of this type of lot is that it is low in cost and can provide a low cost means of determining the demand for this type of service. The disadvantages include the need to negotiate a formal agreement to cover rent, maintenance, repairs, and

## *Figure 10-11*
## *Street-Side Bus Stop Designs*

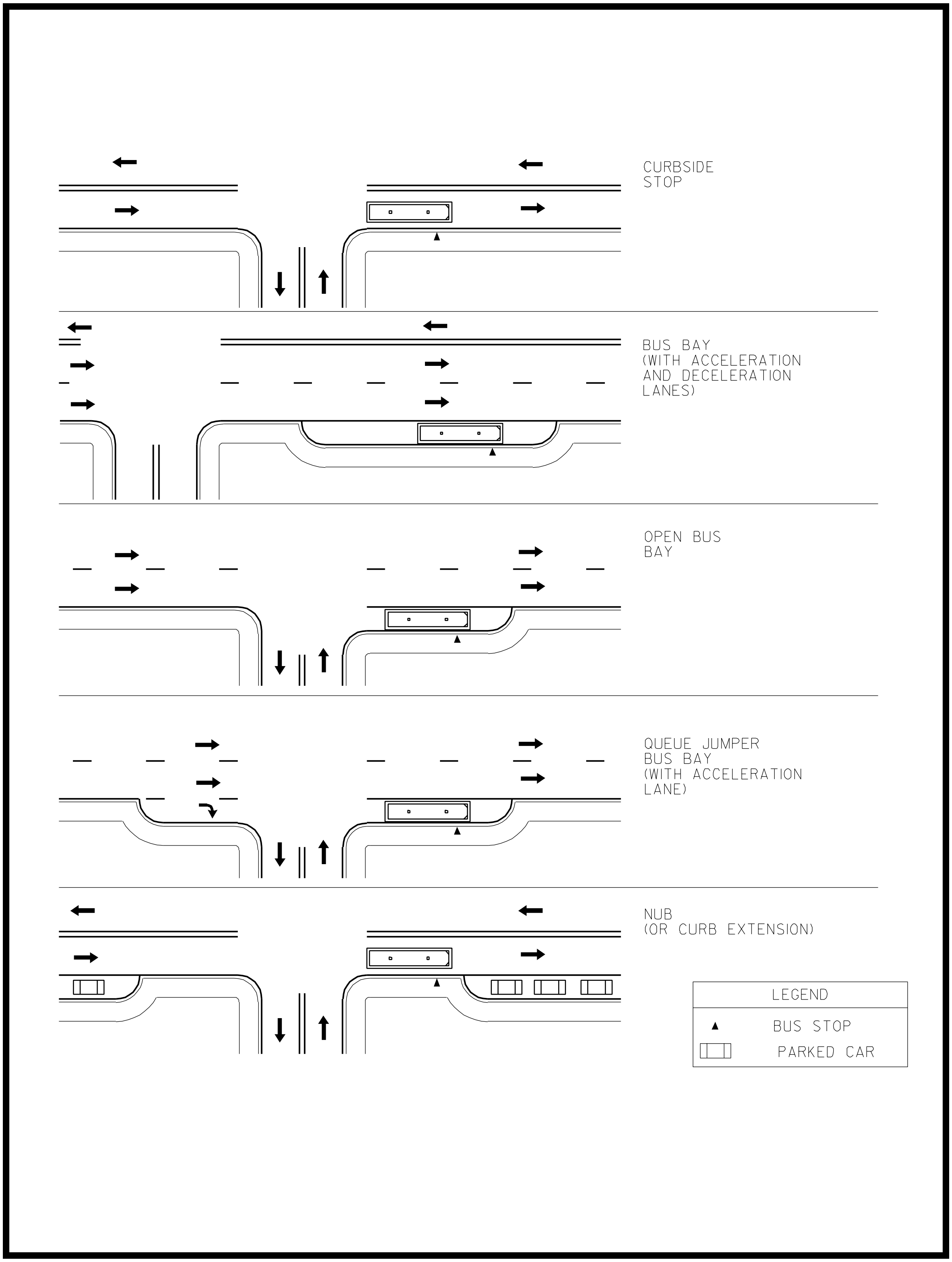
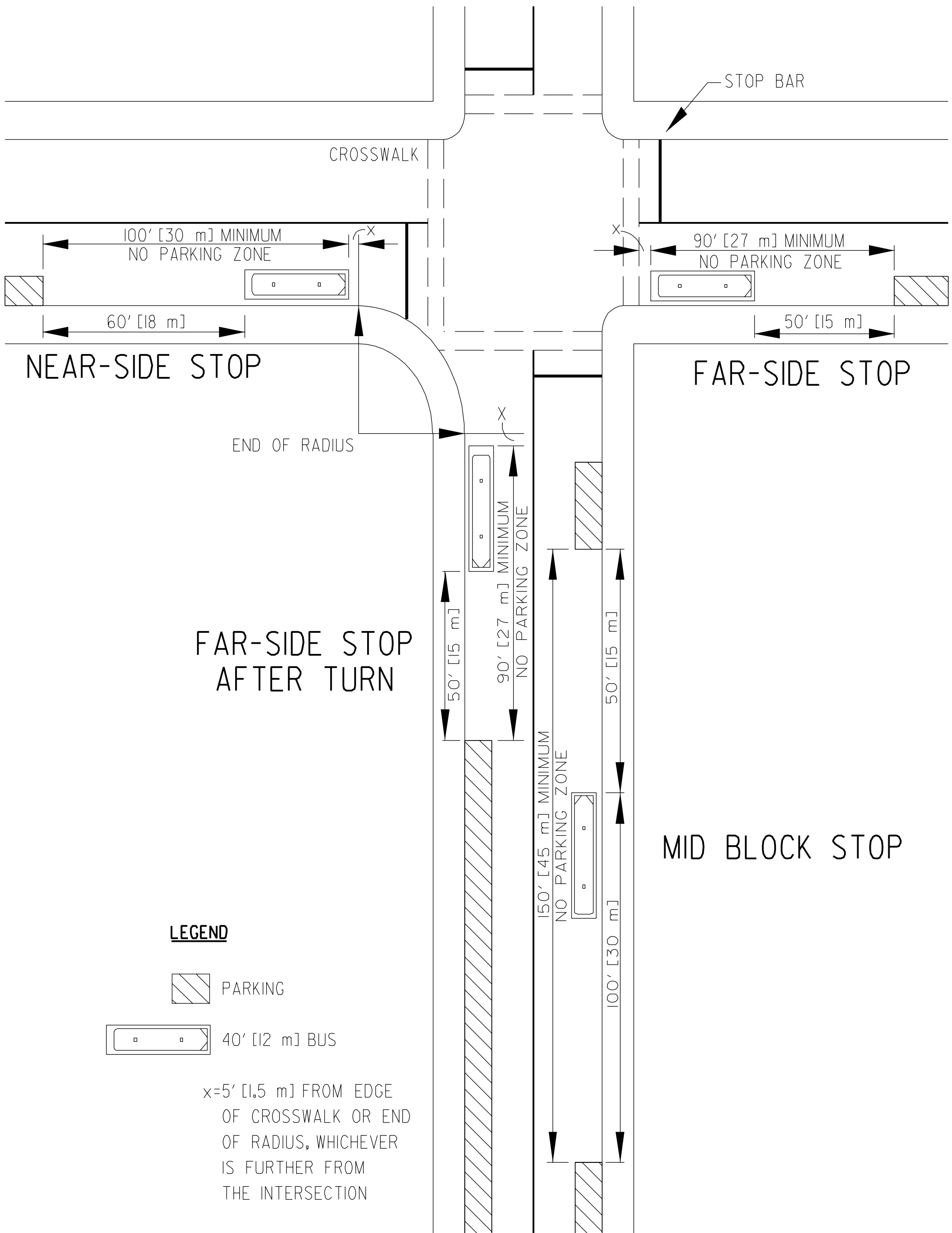
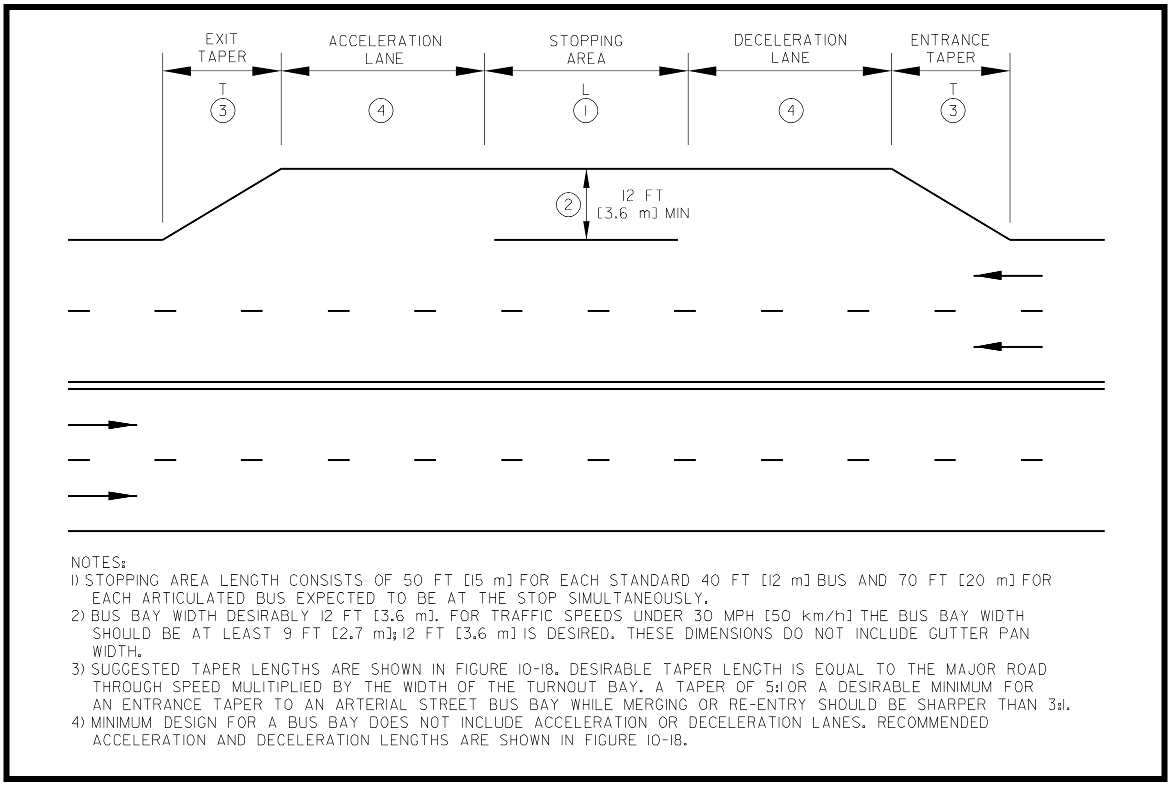


***Figure 10-12***
***Typical Dimensions for On-Street Bus Stops***




NOTES:
1) ADD 20 ft [6 m] TO BUS STOP ZONES FOR AN ARTICULATED BUS.
2) INCREASE BUS STOP ZONE BY 50 ft [15 m] FOR EACH ADDITIONAL STANDARD 40 ft [12 m] BUS OR 70 ft [20 m] FOR EACH ADDITIONAL 60 ft [18 m] ARTICULATED BUS EXPECTED AT THE STOP SIMULTANEOUSLY.

## Figure 10-13
## Typical Bus Bay Layout



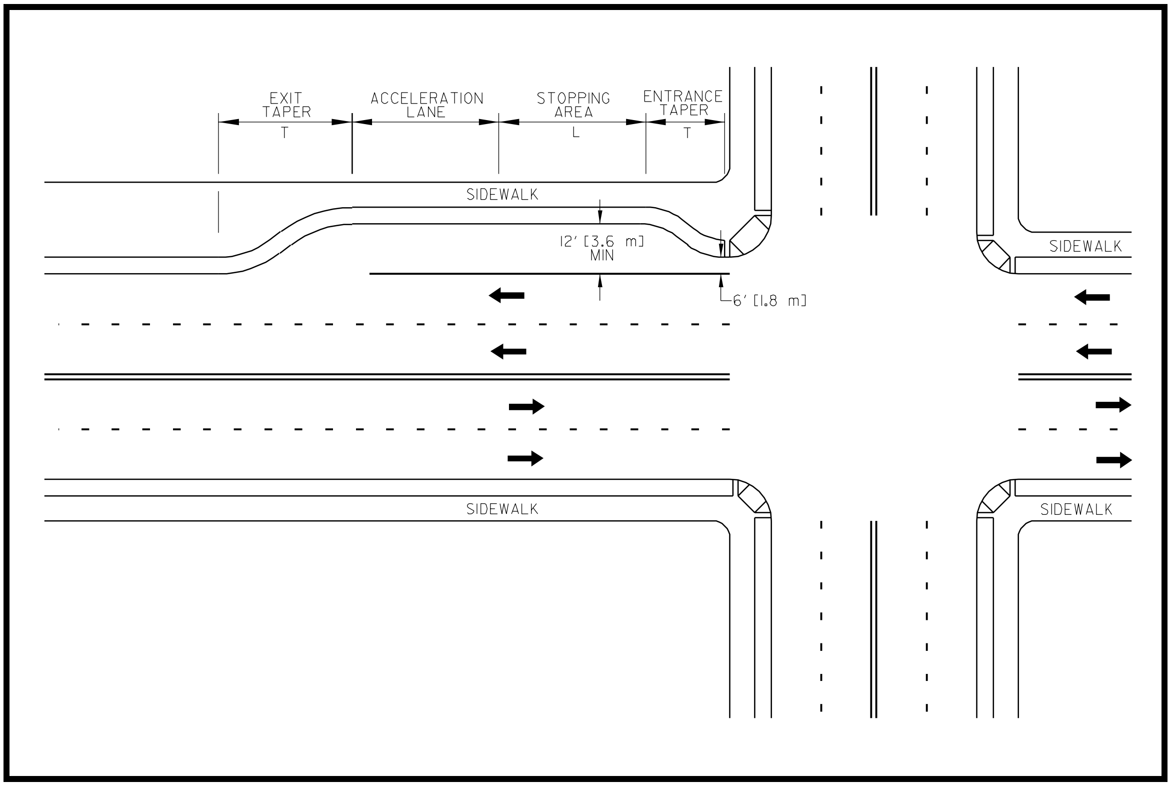

## Figure 10-14
## Typical Bus Bay Dimensions

| Through Speed mph [km/h] | Entering Speed[a] mph [km/h] | Length of Acceleration Lane ft [m] | Length of Deceleration[b] Lane ft [m] | Length of Taper ft [m] |
|---|---|---|---|---|
| 35 [55] | 25 [40] | 250 [75] | 184 [55] | 170 [50] |
| 40 [60] | 30 [50] | 400 [120] | 265 [80] | 190 [60] |
| 45 [70] | 35 [55] | 700 [215] | 360 [110] | 210 [65] |
| 50 [80] | 40 [60] | 975 [300] | 470 [145] | 230 [70] |
| 55 [90] | 45 [70] | 1400 [425] | 595 [180] | 250 [75] |
| 60 [100] | 50 [80] | 1900 [580] | 735 [225] | 270 [80] |

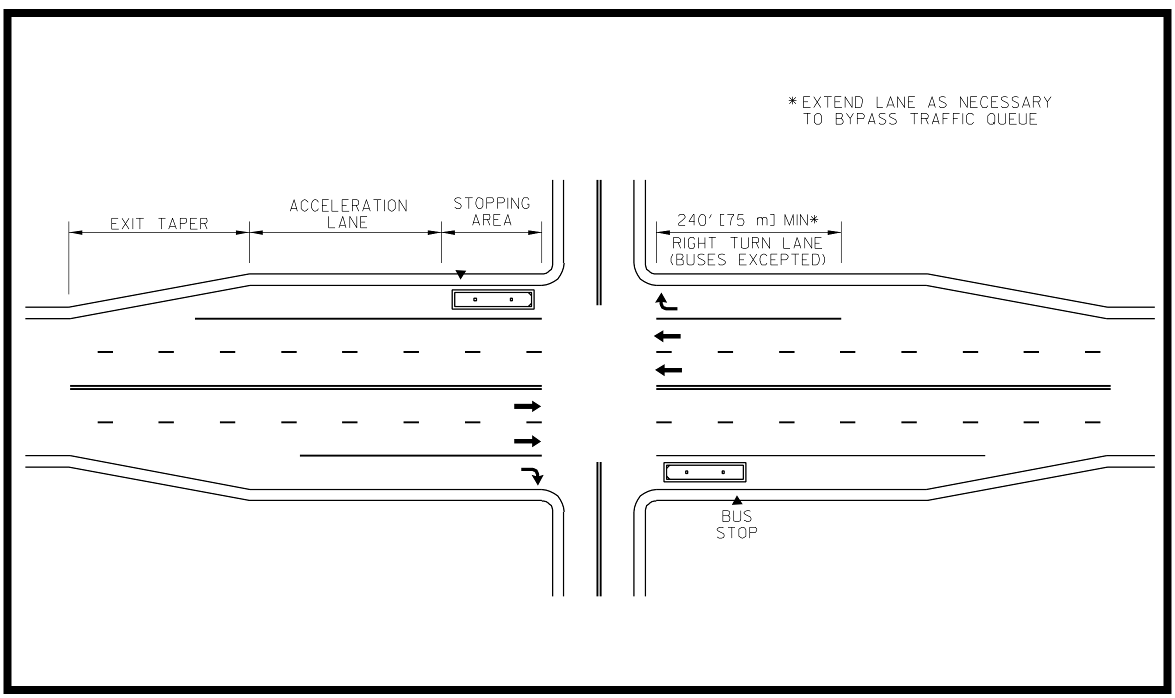
[a] Bus speed at end of taper, desirable for buses to be within 10 mph [15km/h] of travel lane vehicle speed at end of the taper.

[b] Based on 2.5 mph/sec [5 km/sec] deceleration rate.

## *Figure 10-15*
## *Partial Open Bus Bay*

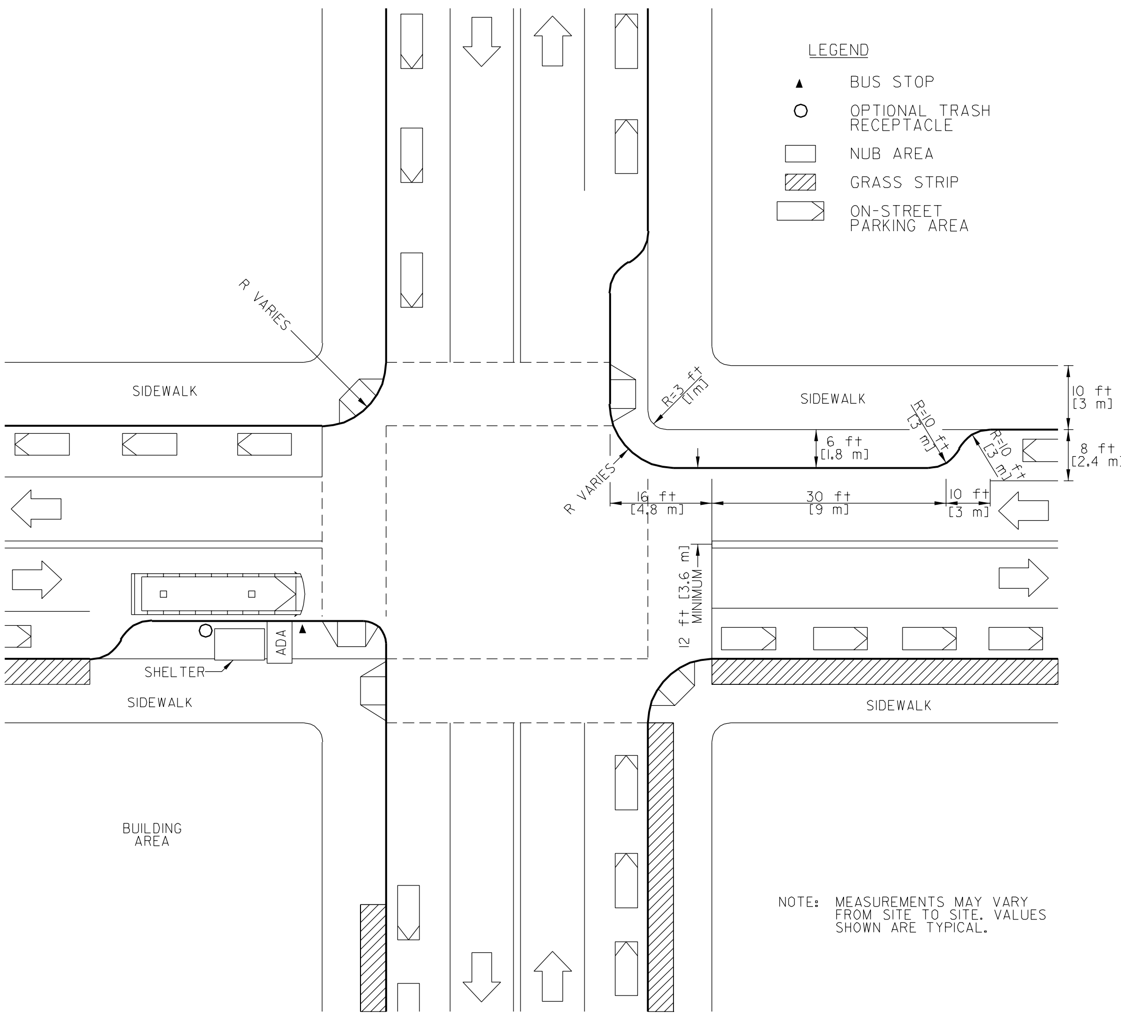



## *Figure 10-16*
## *Queue Jumper Bus Bay*




Notes on Figure 10-13 are applicable to Figures 10-15 and 10-16.

# Figure 10-17
# Nub Bus Bay



termination of use. In addition, the lot may not be laid out or easily adapted to serve transit and its associated pedestrian-automobile conflicts, particularly during peak business seasons.

The need for park-and-ride facilities is influenced by many factors. The following characteristics influence utilization:

- A concentration of work trips to a central location, High levels of traffic congestion on destination routes,
- Limited, inconvenient and/or expensive parking at destinations,
- Frequent transit service available from the park-and-ride facility, and
- Time savings due to preferential treatment of high occupancy vehicles.

In most cases, park-and-ride facilities and the supporting transit services are oriented to a major destination, usually the central business district (CBD). However, in some cases service may be oriented to another major activity center, or service may be provided to more than one destination. General guidelines are discussed in this section. Refer to AASHTO's *Guide for the Design of High-Occupancy Vehicle Facilities* and *Guide for the Design of Park-and-Ride Facilities* and FHWA's *Park-and Ride Facilities: Guide for Planning, Design and Operation* for more detailed information.

### 10.11.1 LOCATION

Lot location is a very critical element in the success of a park-and-ride lot. DTC, the project management team, the public, local agencies and communities are involved in this decision. The general rules for locating park-and-ride facilities are (1) locate them where there is easy access to and egress from the lot for both transit and automobiles and (2) locate them where they will be used e.g. in the desired direction of and along the route of the users. Other factors considered are the geographical location, the site conditions, the anticipated site improvement costs, and the potential user costs in out of pocket cost and personnel time.

Geographical considerations are:

- Is it within a densely used transportation corridor and close to the major roadway(s)?
- Is it located with good site visibility from the major roadway(s)?
- Is the distance to activity centers great enough to encourage its use?
- Is it conveniently accessible—on the desired travel path with easy ingress and egress?
- Does it fit into local traffic patterns?
- Does it fit acceptable commuter driving patterns?
- Does it or can it be tied into bicycle routes?
- Is it located prior to congested roadways with easy access?
- Is the site near or can it be served by a transit service?

Site considerations have varied factors such as:

- Impact on the environment and local communities i.e. is it perceived as a community asset?
- Is the site large enough to serve the projected usage?
- If successful, is there room for expansion?

- Does the adjacent area and streets have parking that is more convenient than a park-and-ride site?

- Is or can the site be made secure?

Several cost variables must be considered including:

- Land purchase value.

- Ease of acquisition, a willing seller.

- Site preparation, construction, and on-going maintenance.

- User costs—estimated vehicle operating cost to drive to the site, parking fees, and transit fares.

- User time—time from commuter's home to the site, waiting time for transfer to high-occupancy mode, and walking time to desired activity center.

One of the simplest methods of site evaluation is to observe in the field and inventory sites where people park in groups, usually at intersections or vacant lots. Addressing this need by providing better facilities at or near these areas may increase ride sharing.

Park-and-ride lots and amenities for transfer of passengers to transit routes are coordinated by DTC.

## 10.11.2 DESIGN

The designer must consider the use to be made of the facility. The design of a park-and-ride lot for car and vanpoolers can be quite simple, a convenient, graveled or paved parking area with safe access to an arterial route (via collector or local roads).

Design considerations are more complex when the lot must serve many users of various modes including short and long-term commuters, buses, pedestrians, bicyclists and motorcyclists, and maybe even a kiss-and-ride option. The design of the lot should provide for each mode. The primary concern during the design phase is safe, efficient transfer and traffic flow for all potential users and transportation modes. Where possible, the differing arrival modes should be allowed separate access points. In addition, the site should have provisions for adequate numbers of useable parking spaces, facilities that are comfortable, safe, and attractive and accessibility for elderly and disabled patrons.

Parking provided in a central business district is for the convenience of both employees and customers. This creates competition for the use of park-and-rides. Park-and-rides are a user's choice, making them dependent upon perceived benefits to the user either in time and/or cost savings. This requires the designer to address the user's special characteristics and provide cost-effective designs that are safe, convenient, and reflective of other values considered by the patrons in making parking decisions.

## 10.11.3 ACCESS

Access to the site is an important design feature requiring internal and external traffic analysis and selection of adequate design criteria. The goals are easy maneuverability for the categories of vehicles allowed on the lot, minimizing potential traffic impacts on local roadways and/or major streets, and providing safe operations both on and off the lot.

Access to the lot should not increase congestion on the major highway that it serves nor add a major conflict point to the route. For this reason, direct access by private automobiles from the lot to a major arterial route is usually not provided. However, direct access for buses is often desirable. Usually, the most efficient access point to a park-and-ride lot will be on a collector or local street intersecting the arterial.

Locating the facility on the right side for inbound traffic on a two-way roadway will allow most users to turn right into the lot, thus eliminating the hazard of crossing an opposing traffic stream. It is likely that maximizing the accessibility for inbound trips will be more effective in attracting users than improving the flow for exiting outbound traffic. Figure 10-18 shows four typical entrance and exit configurations. It is desirable to provide separate one-way entrance and exit drives to minimize crossing conflicts. Note that the access points for the lot should be located at least 150 ft [45 m] from an intersection with the cross-street and 150 ft [45 m] between access points. When there are no more than 150 parking-stalls these distances may be reduced to 100 ft [30 m]. As parking stall capacity increases above 300 stalls, all the external and internal design parameters, circulation patterns and recognition of differing modes become more critical and must be carefully evaluated.

### 10.11.4 INTERNAL CIRCULATION

Major circulation routes in the lot should be located at the periphery of the parking area to minimize pedestrian-vehicle conflicts. For design, the priority sequence is feeder buses, taxis, kiss-and-ride, then park-and-ride with emphasis on the safety needs of bicyclists and pedestrians. The control vehicle in design is the bus. The ingress, egress and internal layout are most influenced by the bus's turning radius and size. Lots designed to serve cars only will probably not accommodate buses and will be avoided by the drivers. Wherever possible buses and cars should not be mixed. Where transit service is available, circulation routes should be designed for easy bus movement, efficient terminal operation and convenient passenger transfer. A one-way roadway pattern is desirable with two lanes provided in the bus stop area for passing the stopped bus.

When passenger-waiting areas are needed, they should be located in a central area with the various user modes surrounding the waiting area or at one end of the lot and parking for the various modes extending radially from the waiting area. Internal circulation design should give priority to fast and easy ingress and egress for transit buses, paratransit vehicles and kiss-and-ride vehicles. In shared use facilities, such as shopping centers or churches, the waiting and designated parking areas should located away from main buildings as to not interfere with normal activities.

Some of the general considerations for design of internal circulation are:

- Drivers should not be confronted with multiple choices at the same time;
- Access points should be spaced to provide for maneuvering and minimize conflicts;
- Access points should be designed to meet demand capacity;
- Flexibility to adjust to changes in operation should be available;
- The terminal/waiting area for high use lots should be located off-street but have convenient access to and from the major roadway;
- When transit services are provided and the lot also serves car/van pool formation, the car/van parking should be located in an area removed from the transit operation;
- HOV access and circulation should be separated from car access and circulation whenever possible; and

- Simple, clear signing.

**10.11.5 BUSES**

As previously discussed, where buses load and unload within the parking lot, traffic flow should be such that buses and automobiles do not conflict. Buses require adequate room for decelerating, proper turning radii, maneuvering into and out of an adequate loading area, and returning to the mainline traffic flow. Refer to Chapter 7 of this manual and the Green Book for design criteria such as required turning radii for bus operation.

**10.11.6 KISS-AND-RIDE FACILITIES**

A kiss-and-ride facility is located so that transit or commuter passengers can easily and safely access the terminal or loading zone with minimum conflicts with other vehicles; see Figure 10-19. To accomplish this, circulation in the kiss-and-ride facility should be one-way and flank the terminal or loading area. Parking should be at 45 degrees to allow for pull through and face the terminal or loading zone. To operate properly it is usually necessary to enforce kiss-and-ride restrictions.

**10.11.7 PEDESTRIANS**

Two pedestrian movements must be provided for park-and-ride lots that serve bus routes: a direct and safe approach from adjacent streets to the bus stop and pedestrian access from the parking area. Pedestrian circulation in parking lots is provided by aisles and crosswalks or, in larger lots, by walkways. The pedestrian path from any parking stall to the bus stop should be as direct as possible.

**10.11.8 BICYCLES AND MOTORCYCLES**

It is important to provide adequate bicycle storage racks at park-and-ride lots where large concentrations of bicycle traffic are expected. Similarly, a special parking area for motorcycles will improve utilization of space. Motorcycle storage should be on Portland cement concrete to prevent stands from sinking into hot asphalt pavement. Provisions for locking both bicycles and motorcycles to prevent theft are needed. This includes bicycle racks and lockers.

**10.11.9 DISABLED**

At lots for transfer to buses, the design should consider provisions for safe and convenient access for the elderly and disabled. Design requirements and provisions for disabled parking shall be in conformance with the *Americans with Disabilities Act of 1990* and the State of Delaware *Architectural Accessibility Standards.*

Facilities for the disabled should also be designed in accordance with the following:

- Disabled persons should reach the bus loading zone without crossing any access roads;
- Loading areas must meet ADA space requirements;
- Disabled persons must never be forced to travel behind parked cars; and
- Suitable ramps must be provided.

**10.11.10 PARKING DIMENSIONS AND LOT LAYOUT**

Parking areas and roadway layout for park-and-rides can be designed in much the same manner as other parking facilities. Facilities that interact with transit, where DTC does not specify a bus size, should use a 40 foot [12 m] transit vehicle as the design vehicle. Standard dimensions for car parking stalls are shown in Figure 10-20.

For design purposes only two size stalls should be considered—standard and intermediate. If compact car parking is to be provided, it should be in a prime location or the driver will select more convenient available stalls. Combining several different types of stalls also creates an undesirable and more complicated signing layout. If there is adequate room, limiting the design to accommodate the standard stall size, 9 by 18.5 ft [2.7 by 5.6 m] is preferred. The minimum bus-parking stall should be 13 by 32 ft [4 by 15.25 m].

***Figure 10-18***
***Typical Car Parking Dimensions***

| Size | Stall Width ft [m] | Stall Length ft [m] | Aisle Width ft [m] |
|---|---|---|---|
| **Standard** | 8.5-9.5 [2.6-2.9] | 18-20 [5.5-6.0] | 24-26 [7.5-8.0] |
| **Inter-mediate** | 8.0-9.0 [2.4-2.7] | 16-18 [4.9-5.5] | 22-24 [6.7-7.3] |
| **Compact** | 7.5-8.5 [2.3-2.6] | 15-17 [4.6-5.2] | 20-22 [6.0-6.7] |

Substandard stall and aisle widths are false economy. Although they permit marking more stalls in a given area, vehicles tend to encroach upon adjacent stalls such that one or more spaces are unavailable for use. The end result is no gain in actual space usage.

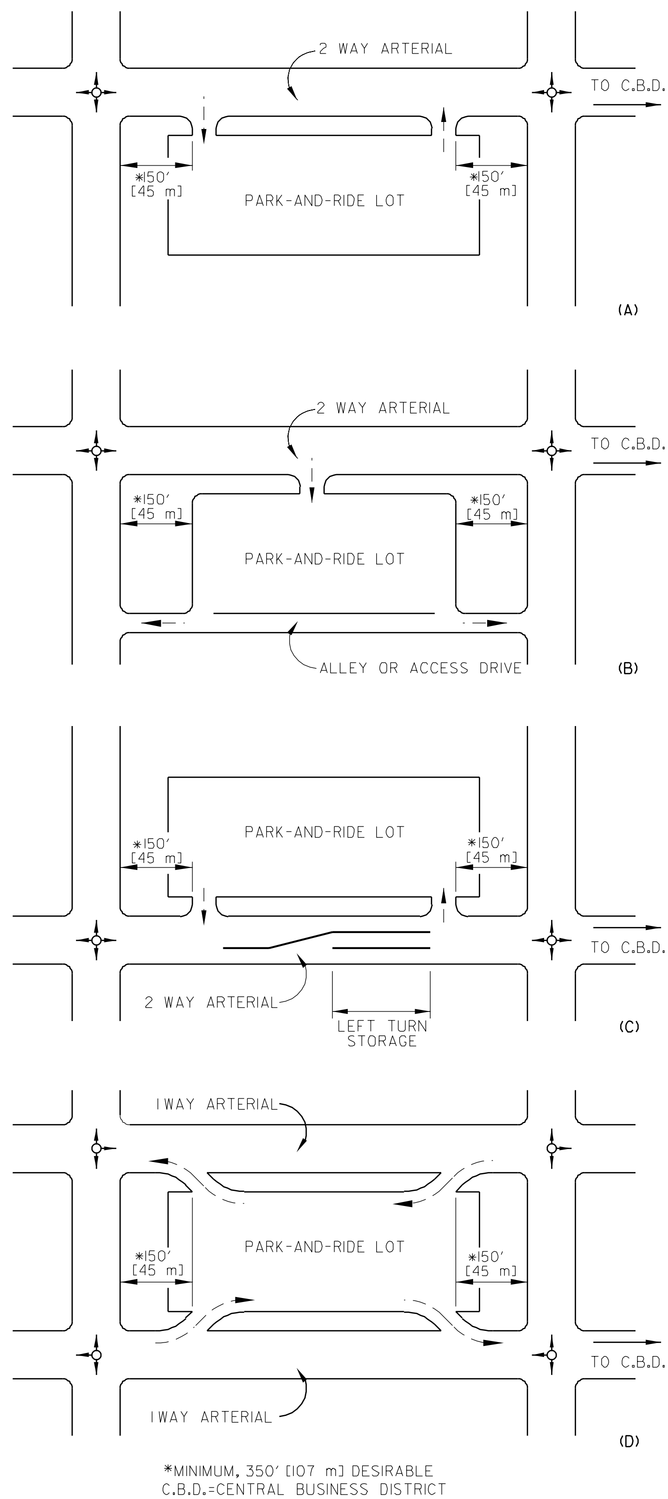
Vehicles and other objects should be excluded from corners or parking spots where it is necessary to provide adequate intersection sight distances. Islands at the end of rows should be considered when laying out the lot. For pedestrian safety, the parking stalls and aisles should be parallel to the direction of the desired pedestrian flow. For efficient land area use, a row of parking on each side of the aisle is preferred.

Aisle width is a function of the parking angle and stall width. One-way aisles are generally used with angle parking and two-way circulation is generally used with 90-degree parking. Aisle lengths should not exceed 400 ft [120 m] to limit pedestrian walking distance. One-way aisles should favor counterclockwise circulation with head-in parking only. Due to lower vehicle undercarriage heights, a 6 in [150 mm] curb is recommended where head-in parking is being considered. Sidewalks should be a minimum of 5 ft [1.5 m] and loading areas should be 12 ft [3.6 m] wide. Pedestrian paths from parking spaces to loading areas should be as direct as possible. All sidewalks and curb areas are to be in conformance with ADA standards.

Figures 10-21 and 10-22 provide data for planning stall layouts for standard stall sizes of 9 by 18.5 ft [2.0 by 5.6 m]. Layouts for intermediate and compact stall sizes are available in the AASHTO Green Book.

The parking area should be sloped to provide positive drainage. Ponding water in a lot is undesirable for both vehicle and pedestrian movement, particularly where freezing may create icy spots. The recommended minimum grade is 1%, the desirable is 2%, and the maximum is 5%. The designer should provide adequate access and areas for snow removal and/or storage. The pavement selection needs to recognize that a variety of traffic loads, particularly when transit is expected, may be applied to the lot and the pavement type and strength designed accordingly.

### *Figure 10-19*
### *Park-and-Ride Access Configuration*



## *Figure 10-20*
## *Example of Kiss-and-Ride Parking Lot*

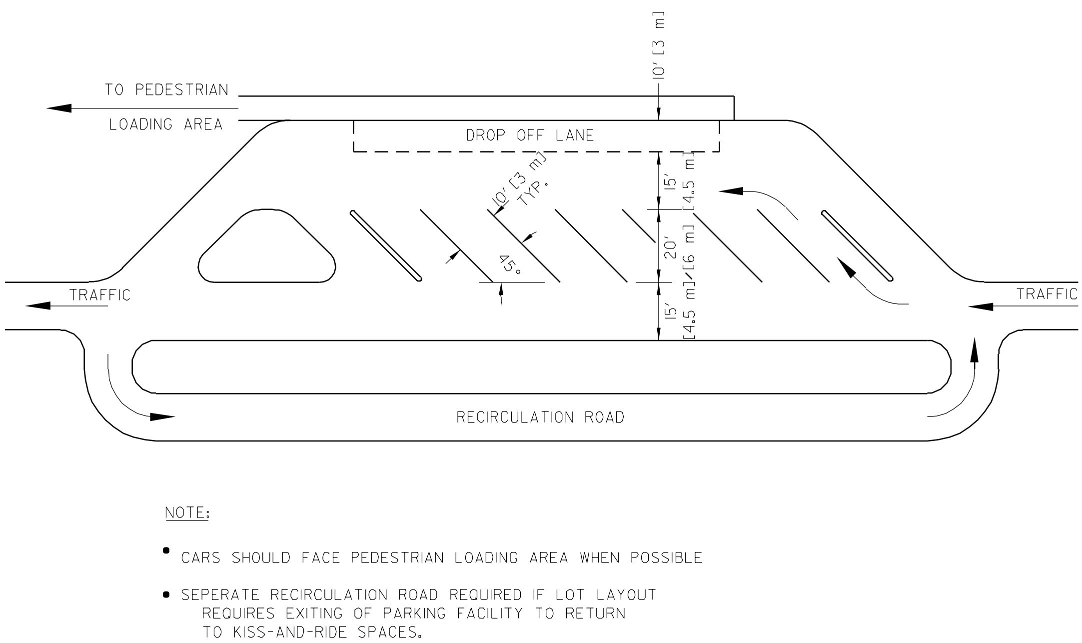


**Figure 10-21**
**Stall Layout for Standard Vehicle (Car)**

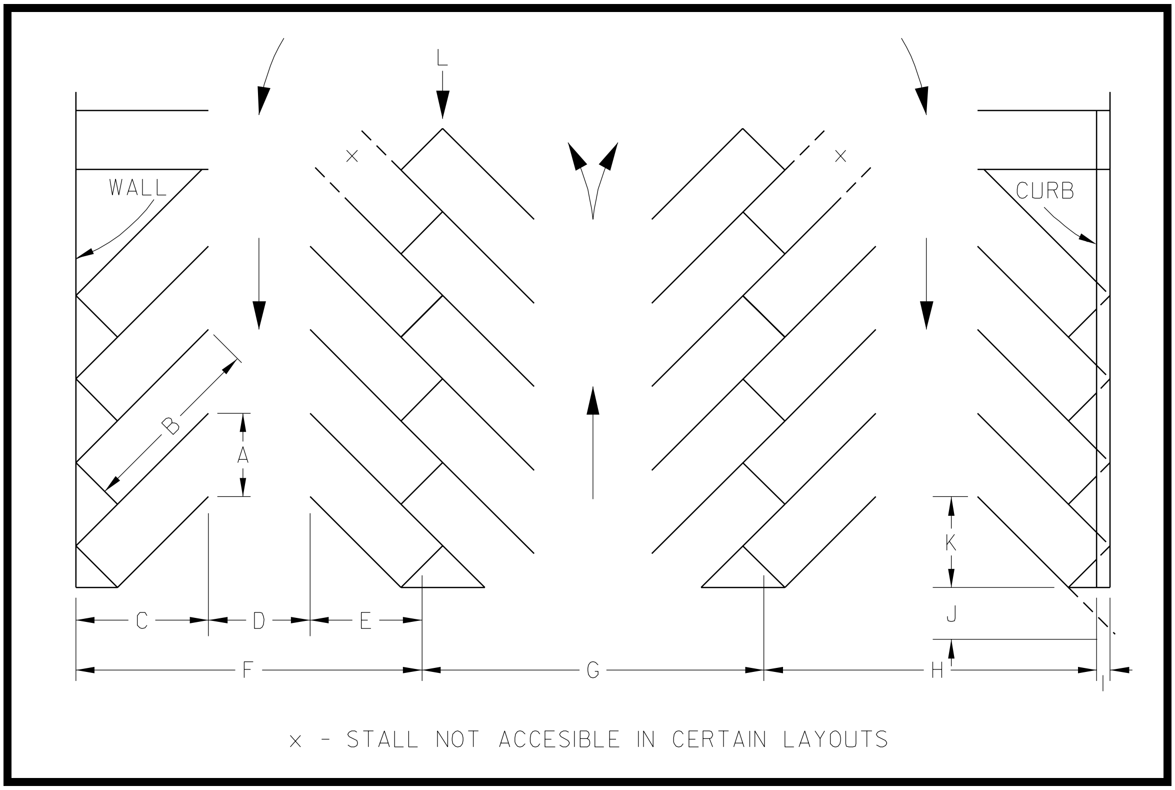


***Figure 10-22***
***Stall Dimensions for Standard Vehicle (Car)***

| Dimension ft [m] | As shown in Figure 10-25 | Angle | | | |
|---|---|---|---|---|---|
| | | $45^0$ | $60^0$ | $75^0$ | $90^0$ |
| Stall width, parallel to aisle | A | 12.7 [3.9] | 10.4 [3.2] | 9.3 [2.8] | 9.0 [2.7] |
| Stall length of line | B | 25.0 [7.6] | 22.0 [6.7] | 20.0 [6.1] | 18.5 [5.6] |
| Stall length of line | C | 17.5 [5.3] | 19.0 [5.3] | 19.5 [5.9] | 18.5 [5.6] |
| Aisle width between stall line | D | 12.0 [3.6] | 16.0 [4.9] | 23.0 [7.0] | 26.0 [7.9] |
| Stall depth, interlock | E | 15.3 [4.7] | 17.5 [5.8] | 18.8 [5.7] | 18.5 [5.6] |
| Module, wall to interlock | F | 44.8 [13.7] | 52.5 [16.0] | 61.3 [18.7] | 63.0 [19.2] |
| Module, interlocking | G | 42.6 [13] | 51.0 [15.5] | 61.0 [18.6] | 63.0 [19.2] |
| Module, interlock to curb face | H | 42.8 [13.0] | 50.2 [15.3] | 58.8 [18.0] | 60.5 [18.4] |
| Bumper overhang (typical) | I | 2.0 [0.6] | 2.3 [0.7] | 2.5 [0.8] | 2.5 [0.8] |
| Offset | J | 6.3 [1.9] | 2.7 (0.8] | 0.5 [0.2] | 0.0 [0.0] |
| Setback | K | 11.0 [3.3] | 8.3 [2.5] | 5.0 [1.5] | 0.0 [0.0] |
| Cross aisle, one-way | L | 14.0 [4.3] | 14.0 [4.3] | 14.0 [4.3] | 14.0 [4.3] |
| Cross aisle, two-way | — | 24.0 [7.3] | 24.0 [7.3] | 24.0 [7.3] | 24.0 (7.3) |